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FINAL

WORK PLAN

PILOT SCALE TREATABILITY STUDY FOR EXPLOSIVES-CONTAMINATED SOIL

NAVAL WEAPONS STATION YORKTOWN
YORKTOWN, VIRGINIA

CONTRACT TASK ORDER 0365

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Prepared for:

DEPARTMENT OF THE NAVY
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ACRONYMS AND ABBREVIATIONS

Baker	Baker Environmental, Inc.
CLEAN	Comprehensive Long-Term Environmental Action Navy
CLP	Contract Laboratory Program
CTO	Contract Task Order
DNB	dinitrobenzene
DNT	dinitrotoluene
DoN	Department of the Navy
FS	Feasibility Study
FSP	Field Sampling Plan
HASP	Health and Safety Plan
HMX	Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
HDPE	High-Density Polyethylene
IDW	Investigation Derived Waste
LANTDIV	Naval Facilities Engineering Command, Atlantic Division
mg/kg	Milligram per Kilogram
NEESA	Naval Energy and Environmental Support Activity
OHM	OHM Remediation Services
PPE	Personal Protective Equipment
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
QC	Quality Control
RDX	Hexahydro-1,3,5-trinotro-1,3,5-triazine
RI	Remedial Investigation
SABER	Simplot Anaerobic Bioremdiation Process
SIMPLOT	J.R. Simplot Company
TCA	trichloroethane
TCE	trichloroethene
TNB	Trinitrobenzene
2,4,6-TNT	Trinitrotoluene
USEPA	United States Environmental Protection Agency

ACRONYMS AND ABBREVIATIONS
(Continued)

VDEQ	Virginia Department of Environmental Quality
WES	Waterways Experimental Station
WPNSTA Yorktown	Naval Weapons Station Yorktown, Yorktown, Virginia

EXECUTIVE SUMMARY

INTRODUCTION

This document presents the Site-Specific Work Plan addressing the scope of activities to be conducted during the performance of the Pilot Study for explosives-contaminated soil at Site 7 at Naval Weapons Station Yorktown (WPNSTA Yorktown), Yorktown, Virginia. This document has been prepared by Baker Environmental, Inc. (Baker) under Contract Task Order (CTO) -0365 of the Department of the Navy's (DoN's) Comprehensive Long-Term Environmental Action Navy (CLEAN) Program.

This Site-Specific Work Plan is to be used in conjunction with the Master Project Plans for WPNSTA Yorktown submitted and approved under a separate cover, and the Site-Specific Project Plans for the Remedial Investigation (RI) and Feasibility Study (FS) for Site 7 also submitted and approved under a separate cover.

Several sites at WPNSTA Yorktown, such as Sites 6, 7, 9, and 19 have explosives-contaminated soil and/or sediment as the result of past explosive disposal and loading/processing operations. These sites may require remediation to protect human health and/or the environment. The U.S. Army Corps of Engineers Waterways Experiment Station (WES) in Vicksburg, Mississippi has recently performed a comprehensive bench-scale Treatability Study to determine favorable biological technologies to treat explosives-contaminated soil and sediment. The WES studies concluded that a few of the technologies produced favorable results at the bench-scale level: an anaerobic technology utilizing a potato starch developed by J.R. Simplot Company (Simplot) called the Simplot Anaerobic Bioremediation Process (SABRE®) technology, an aerobic technology using native consortia, molasses and Tween 80 (a surfactant) and an anaerobic technology using molasses and Tween 80. Of these technologies, the SABRE® process has been successfully demonstrated at other sites and is ready for field pilot testing at WPNSTA Yorktown.

A field-scale Pilot Study will be completed to determine the technical implementability, effectiveness, and future costs of the Simplot process to treat explosives-contaminated soil and sediment. The Pilot Study will be performed as a joint effort by the Navy, WPNSTA Yorktown,

Baker, and OHM Remediation Services (OHM). Baker will subcontract to Simplot to provide their proprietary and patented technology. The contaminated soil/sediment will be collected from Site 7.

SITE HISTORY AND BACKGROUND INFORMATION

Site 7 is a small drainage area located adjacent to wetlands and along a small tributary to Felgates Creek. The Site 7 discharge area received explosives-contaminated wastewater from Loading Plant 3 during 1945 to 1975. The weapons loading operations released chlorinated solvents and explosive compounds such as trinitrotoluene (TNT) and hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) to the drainage area. Currently, the drainage way has reverted to a natural drainage area and receives no discharge from the Plant 3 complex.

A variety of environmental investigations have been conducted at Site 7. Most recently, a Round Two RI was conducted. A complete presentation of contaminants detected in various media at Site 7 is presented in the Round Two RI Report.

RESULTS OF THE BENCH-SCALE TREATABILITY STUDY

The final bench-scale treatability study report has not been completed. Nonetheless, WES has concluded that based on the results from the bench-scale studies, the aerobic bioslurry technology utilizing native soil consortia, Tween 80 and molasses; the anaerobic bioslurry technology using Tween 80 and molasses; and the anaerobic biocell utilizing the Simplot process to be the most potentially effective treatment methods for WPNSTA Yorktown soil.

Based on the results of the bench-scale treatability study, LANTDIV has decided to further the evaluation of the effectiveness of the Simplot technology by conducting a field-scale pilot study at WPNSTA Yorktown. LANTDIV may decide to conduct a pilot study implementing the Tween 80 and molasses bioslurry in the future.

PILOT STUDY

The Pilot Study will involve the implementation of the SABRE® technology for the remediation of explosives-contaminated soil. This technology operates on the premise of microbiological

interactions and contaminant degradation pathways. The treatment phase of the Pilot Study will be conducted until confirmatory analytical laboratory results of soil samples collected during the Pilot Study indicate that the concentrations of explosive compounds have met the following treatment goals:

• TNT	30 mg/kg
• RDX	100 mg/kg
• HMX	12,000 mg/kg
• Amino-DNTs	80 mg/kg
• 1,3,5-TNB	12 mg/kg
• 2,4/2,6-DNT (mixture)	25 mg/kg

Approximately 500 cubic yards of explosives-contaminated soil will be excavated from Site 7 at WPNSTA Yorktown. The soil will be transported to Site 22 where the Simplot biocell structure will be constructed. Note that the reference to a biocell in the remaining text refers to the structure in which the Simplot SABRE® technology will be implemented.

The Pilot Study using Simplot's SABRE® process will be conducted at Site 22 at WPNSTA Yorktown. The Pilot Study will be implemented in the following steps: 1) Mobilization; 2) Biocell Construction; 3) Excavation of Contaminated Soil; 4) Soil Screening and Fluidizing; 5) Soil Placement into Biocell; 6) Mixing the Biocell; 7) Monitoring the Biocell; and 8) Demobilization.

Biocell Construction

The biocell will be constructed in a large flat area at Site 22. The biocell will be an in-ground excavation measuring approximately 86 feet wide by 150 feet long by 7 feet deep. Side slopes will be 1:1. The biocell will be double-lined with an 80-mil high-density polyethylene (HDPE) liner on top, a 6-inch sand layer, and a 60-mil HDPE liner on the bottom. The side slopes of the biocell will be self-supporting without the need for "Geonet" reinforcing. A sand bedding will be laid down to protect the liner. The biocell will be designed to hold 500 cubic yards of soil 2.5 feet deep with 2.5 feet of water above.

Excavation of Contaminated Soil

Explosives-contaminated soil to be used for the Pilot Study will be excavated from Site 7 at WPNSTA Yorktown. Portions of Site 7 (the drainage way) will be cleared of trees and debris. OHM will excavate soil from Site 7 until approximately 500 cubic yards of soil is obtained. The depth of the excavation will be approximately 3 to 4 feet. Confirmatory soil samples will be collected during the excavation activities and analyzed using EnSys® Test Kits to estimate the lateral and vertical extent of contamination.

The excavated soil will be loaded into dump trucks and transported to Site 22. Following the excavation activities, the disturbed areas at Site 7 will be restored. These areas will be backfilled, regraded, and revegetated.

Soil Screening and Fluidizing

The excavated soil from Site 7 will be transported to the soil screening area at Site 22. The soil will be placed on a vibrating one inch screen so that the soil is screened to a desirable size. Oversized material will be pressure washed and returned to Site 7.

Simplot's fluidizer tank will be positioned under the screen collection hopper. The screened soil will be transferred to the fluidizer with the oversized material decontamination water. Additional water may be mixed with the soil in the fluidizer.

Soil Placement into Biocell

The soil/water mixture will be transferred from the fluidizer to the biocell with the use of a low pressure slurry pump. Approximately 2.5 feet of soil/water mixture will be placed into the biocell, with an additional 2.5 feet of water added on top of the soil. The biocell will be designed to accommodate up to three feet of soil/water mixture and the additional water.

Chemicals, nutrients, and additives such as pH buffers, a carbon source, and Simplot inoculum will be placed in the biocell to start the degradation process. The carbon source will be a Simplot potato starch by-product from one of their food processing plants.

Mixing the Biocell

The contents of the biocell will be mixed two to three days a week for eight weeks or until the explosive contaminants have met the treatment goals. A hydromixing system suspended from a mobile gantry unit will be implemented for the mixing operations. The mixing system will contain intake suction screens and injection hydro lances. The system works by drawing water from the top of the biocell and pumping it under pressure into the soil without aerating the biocell in the process. The gantry system, which suspends the mixing unit, rides on two rails along the length of the biocell. The purpose of the mixing is the mass transfer of contaminants from the soil to the liquid medium, making them more available to the microbial population for degradation.

Monitoring the Biocell

The contents of the biocell will be monitored three times per week during the treatment phase of the Pilot Study. Field parameters will include pH, redox potential, and temperature. A pH target of 7.0 should be easily achieved and maintained once the SABRE® process has begun. A redox potential of less than -200 mV is sufficiently low enough to maximize degradation rates. The target temperature level for the biocell is a minimum 18° C.

In addition to the field parameters, soil/water mixture samples will be collected from the biocell three times per week for laboratory and/or field test kit analysis. The field test kit samples will be analyzed with TNT and RDX EnSys®test kits. These test kits will be able to estimate concentrations for TNT; RDX; HMX; 2,4-DNT; 2,6-DNT; 1,3,5-TNB; and 1,3-dinitrobenzene (1,3-DNB). The laboratory samples will be analyzed for nitramines/nitroaromatic compounds using SW846-Method 8330. The results from these samples will be evaluated to determine when the soil has reached the treatment goals.

When the laboratory results confirm that the contaminant levels have met the treatment goals, the treated biocell contents will be left in place. Based on other field tests conducted by Simplot on other sites, it is estimated that the treatment goals will be met within eight weeks of operation of the biocell system. The water in the biocell will be allowed to evaporate. If necessary (e.g., if the biocell is to be reused), the treated soil may be transferred in an unlined evaporation/percolation

impoundment area constructed at Site 22. This would allow for sequential batches of contaminated soil to be treated.

RESPONSIBILITIES

The primary responsibilities of Baker, Simplot, and OHM area listed below.

Baker's responsibilities will include:

- Provide the project management of the Pilot Study
- Provide technical/financial oversight of Simplot (subcontractor)
- Serve as liaison between Simplot, LANTDIV, WPNSTA Yorktown, and the regulatory representatives
- Collect confirmatory soil samples at Site 7 during excavation activities
- Communicate the project status and preliminary test results to LANTDIV, as necessary
- Provide part-time assistance to Simplot with the operation of the hydromixing system
- Collect the biocell monitoring samples including pH, redox potential, temperature, and soil samples for explosive analysis (both for field test kits and for off-site laboratory analysis)
- Manage the IDW generated during the sampling activities of the Pilot Study

Simplot's responsibilities will include:

- Provide the hydromixing system and pumps; the gantry rail system; the fluidizing equipment and pumps, the biocell additives and the Simplot proprietary innoculum
- Provide approval and supervision of the implementation of the SABRE® technology
- Provide oversight with respect to technology transfer and quality assurance
- Provide recommendations on the biocell construction and loading
- Supervise the soil treatment process

OHM's responsibilities will include:

- Provide excavation and construction equipment
- Provide the soil screening system (vibrating screen) and conveyor
- Provide any other miscellaneous equipment and supplies needed for the Pilot Study
- Provide the materials for and construct the biocell
- Construct the concrete anchor trench for the gantry rails
- Install the gantry rails
- Assemble and erect the gantry system

- Clear the area(s) to be excavated at Site 7 and the Pilot Study areas at Site 22 as needed, and provide all necessary erosion prevention controls

- Excavate 500 cubic yards of soil from Site 7 and transport it to the soil screening system at Site 22

- Excavate and stockpile soil from Site 22 taken from the area in which the biocell will be constructed

- Restore the disturbed areas at Site 7

- Operate the soil screening system and stage/manage the oversized materials (return it back to Site 7)

- Properly decontaminate appropriate equipment

- Restore all appropriate areas at Sites 7 and 22

SCHEDULE

Construction of the biocell is anticipated to start in August 1996. The treatment phase of the Pilot Study is anticipated to start in the middle of September 1996 and continue through the beginning of November 1996 (eight week duration). A two week final demobilization period has been assumed. Following the completion of the field portion of the Pilot Study, a Pilot Study report will be prepared to provide a presentation and evaluation of the Pilot Study monitoring results.

1.0 INTRODUCTION

This document presents the Site-Specific Work Plan addressing the scope of activities to be conducted during the performance of the Pilot Study for explosives-contaminated soil at Site 7 at Naval Weapons Station Yorktown (WPNSTA Yorktown), Yorktown, Virginia. The location of WPNSTA Yorktown is presented on Figure 1-1. This document has been prepared by Baker Environmental, Inc. (Baker) under Contract Task Order (CTO) -0365 of the Department of the Navy's (DoN's) Comprehensive Long-Term Environmental Action Navy (CLEAN) Program.

This Site-Specific Work Plan is to be used in conjunction with the Master Project Plans for WPNSTA Yorktown submitted and approved under a separate cover (Baker, 1994a), and the Site-Specific Project Plans for the Remedial Investigation (RI) and Feasibility Study (FS) for Site 7 also submitted and approved under a separate cover (Baker, 1994b). The Master Project Plans include a Work Plan, Field Sampling Plan (FSP), Quality Assurance Project Plan (QAPP), and Health and Safety Plan (HASP). These plans address the full range of potentially applicable activities that could be required throughout the RI/FS process: field investigation activities; sampling and analytical methodologies; health and safety considerations; data evaluation/interpretation methodologies; and other overall project activities. As such, methodology information contained in the Master Project Plans is incorporated by reference in this Site-Specific Work Plan, as applicable.

The Site-Specific Work Plan that follows, which incorporates a HASP Addendum, provides a description of site conditions and the findings of previous investigative work at Site 7, the Plant 3 Explosives-Contaminated Discharge Area. In addition, an overview of the Pilot Study activities including the monitoring plan is addressed in the Work Plan. The Plan also establishes the schedule for completion of the pilot study and the project management and responsibility process.

1.1 Purpose

Several sites at WPNSTA Yorktown, such as Sites 6, 7, 9, and 19 have explosives-contaminated soil and/or sediment as the result of past explosive disposal and loading/processing operations. These sites may require remediation to protect human health and/or the environment. The U.S. Army Corps of Engineers Waterways Experiment Station (WES) in Vicksburg, Mississippi has recently

performed a comprehensive bench-scale Treatability Study to determine favorable biological technologies to treat explosives-contaminated soil and sediment. The WES studies concluded that several technologies produced favorable results at the bench-scale level: an anaerobic technology utilizing a potato starch developed by J.R. Simplot Company (Simplot) called the Simplot Anaerobic Bioremediation Process (SABRE®) technology; an aerobic technology using native consortia, molasses and Tween 80 (a surfactant); and an anaerobic technology using molasses and Tween 80. Of these technologies, the SABRE® process has been successfully demonstrated at other sites and is ready for field pilot testing at WPNSTA Yorktown.

A field-scale Pilot Study will be completed to determine the technical implementability, effectiveness, and future costs of the Simplot process to treat explosives-contaminated soil and sediment. The Pilot Study will be performed as a joint effort by the Navy, WPNSTA Yorktown, Baker, and OHM Remediation Services (OHM). Baker will subcontract to Simplot to provide their proprietary and patented technology. The contaminated soil/sediment will be collected from Site 7.

1.2 Document Organization and Presentation

This document is organized into five additional sections. Section 2.0 summarizes background information and the past site investigation results for Site 7. In addition, Section 2.0 summarizes the results of the recently conducted bench-scale treatability study conducted for the explosives-contaminated soil. Section 3.0 presents the technical approach for the Pilot Study tasks. The work activities that Baker will be responsible for will be detailed in this section. Section 4.0 contains project management and responsibilities. Section 5.0 contains the schedule for the Pilot Study; and Section 6.0 contains the references used to develop this Work Plan. A HASP Addendum is also included as part of this document. All tables and figures for the Work Plan are included at the end of the document.

2.0 SITE DESCRIPTIONS, HISTORY AND RESULTS OF THE BENCH SCALE TREATABILITY STUDY

This section presents a brief discussion of the site descriptions, history and results of the WES bench-scale treatability study. In addition, the section discusses the results of the previous investigations at Site 7 as they relate to explosive contamination. The location of Site 7 is presented on Figure 2-1 along with other sites at WPNSTA Yorktown. The location of the Pilot Scale biocell (Site 22) is also presented on this figure.

2.1 Site History and Background Information

Site 7 is a small drainage area located adjacent to wetlands and along a small tributary to Felgates Creek. The Site 7 discharge area received explosives-contaminated wastewater from Loading Plant 3 during 1945 to 1975. The weapons loading operations released select solvents such as trichloroethene (TCE), and trichloroethane (TCA) and explosive compounds such as trinitrotoluene (TNT) and hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) to the drainage area. Currently, the drainage way has reverted to a natural drainage area and receives no discharge from the Plant 3 complex.

A variety of environmental investigations have been conducted at Site 7. Most recently, a Round Two RI was conducted. A complete presentation of contaminants detected in various media at Site 7 is presented in the Round Two RI Report (Baker, 1996).

Soil and sediment samples collected from the site were analyzed for a wide range of parameters, including nitramine/nitroaromatic compounds (i.e., explosives). Maximum concentrations of explosives detected in soil/sediment at Site 7 during the Round One RI and the Round Two RI are presented in Table 2-1.

2.2 Results of The Bench-Scale Treatability Study

This section reviews the preliminary results of the bench-scale treatability study recently conducted for explosives-contaminated soil at WPNSTA Yorktown. It is noted that a final report and conclusions of the bench-scale study are not available at this time. WPNSTA Yorktown, in

conjunction with the DoN (LANTDIV) and Baker, have assessed the extent of explosives contamination at WPNSTA Yorktown sites, and evaluated various remediation approaches. As part of remediation technology assessments, LANTDIV tasked WES to perform a bench-scale treatability study to determine the feasibility of remediating explosives contaminated soil at WPNSTA Yorktown. This bench-scale treatability study included three soil treatment techniques: anaerobic biotreatment, aerobic biotreatment, and SlurOx treatment. The objectives of the study were to assess and maximize the explosive-degrading potential of indigenous WPNSTA Yorktown soil microbial communities using microcosms of bioslurry or biocell treatment systems. The bioslurry represents the highest level of mixing available; whereas, the biocell is a static system. It is noted that based on preliminary results, the SlurOx system was eliminated from consideration as a possible remediation technique and was not further evaluated as part of the bench-scale study. The following remediation technologies were selected for investigation:

- Aerobic Biocell
- Anaerobic Biocell
- Aerobic Bioslurry
- Anaerobic Bioslurry

The bench-scale treatability for WPNSTA Yorktown was completed in phases. Phase I (conducted from January 1995 to May 1995) consisted of the selection of soil samples; collection, homogenization, and shipment of the samples; soil sample storage; the homogenization and sieving of samples; and chemical and physical characterization of the soil sample. Phase II (conducted from June to July 1995) included the assessment of explosive-degrading potential of soil microflora, selection of enrichments of TNT-degrading microorganisms, assessment of the efficacy of adding exogenous microorganisms to bacteria contaminated soil, and evaluation of the effects of adding the surfactant Tween 80 to the soil during biotreatment. Phase III (conducted from August to September 1995) included selection of surfactant dose and sequential batch tests. Phase IV (conducted from November 1995 to April 1996) was the bioslurry bench-scale study and Phase V (conducted from November 1995 to April 1996) was the biocell bench-scale study. Finally, Phase VI is the reporting phase of the study; WES is currently completing this final phase.

Representative soil samples from several sites at the WPNSTA Yorktown were studied in microcosms designed to simulate bench-scale bioslurry and biocell treatment systems. TNT was

mixed into soil samples and the samples were incubated for 48 hours. The degradation of TNT was determined by monitoring the disappearance of TNT, the appearance of TNT metabolites, and the evolution of carbon dioxide. The effects of the various treatments on the microbial community in the soil were measured by monitoring the total respiration of the soil microbial community in the microcosms and by analysis of polar membrane lipids.

Two types of systems were tested for the biocell and bioslurry bench-scale test: aerobic and anaerobic. The treatment systems to be used in the bench-scale studies were determined based on the results from Phase II and Phase III. The aerobic biocell studies included the following two treatments:

- sterile control
- Tween 80 (a surfactant) and molasses

The anaerobic biocell studies included:

- potato starch
- Tween 80 and molasses
- Simplot method
- molasses
- sterile control

The aerobic bioslurry studies included the following treatments:

- sterile control
- no additives
- Tween 80 and molasses

The anaerobic bioslurry studies included the following treatments:

- potato starch
- Simplot method
- Simplot method with four hour mixing
- sterile control

The bioslurry and biocell systems were sampled routinely over a 10-12 week period for explosives and explosive-related compounds. Soil was sampled and analyzed from the biocell and both soil and water collected from the bioslurry system were analyzed. The following subsections discuss the results from each study.

2.2.1 Biocell Results

The aerobic biocell was not as successful as the anaerobic biocells in the reduction of explosive compounds. The Tween-80 and molasses treatment (aerobic) only demonstrated a 25 percent reduction in total explosives and a 31 percent reduction in TNT in 49 days in the biocell. Whereas the anaerobic systems (Tween 80 and molasses; molasses; Simplot; and potato starch) all showed greater than 90 percent reduction of TNT by day 49.

Figure 2-2 presents a graph of the results of the biocell study for each of the treatment systems with respect to TNT reduction. As shown on this figure, the Tween 80 and molasses treatment appeared to result in the highest level of TNT degradation in the shortest period of time.

2.2.2 Bioslurry Results

By day 21 of the bioslurry study, total explosives were degraded by 89 percent and TNT was degraded by 99.6 percent by the molasses treatment system in the aerobic bioslurry. Anaerobic bioslurry successfully degraded TNT; however, concentrations of RDX, octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX), and dinitrotoluenes did not appear to degrade as fast as in the biocells. The bioslurry study indicated that there was no significant difference between continuous Simplot mixing and the 4-hour Simplot mixing. By day 21, total explosives were only degraded by 66 percent by the potato starch and 59 percent by the Simplot mixture; however, TNT was degraded by 96-percent with the potato starch and 90 percent with the Simplot mixture.

Figure 2-3 presents a graph of the results of the bioslurry study for each of the treatment system with respect to TNT reduction. As shown on this figure, the Tween 80 and molasses (aerobic) appeared to result in the quickest reduction of TNT. The Simplot with 4-hour mixing (anaerobic) and the potato starch (anaerobic) treatment systems also appeared to result in very quick TNT degradation rates. WES has concluded that the aerobic and anaerobic technologies using the molasses and Tween 80 appear to provide the most favorable results.

2.2.3 Bench-Scale Study Conclusions

The final bench-scale treatability study report has not been completed. Nonetheless, WES has concluded that based on the results from the bench-scale studies, the aerobic and anaerobic bioslurry technology utilizing native soil consortia, Tween 80 and molasses and the anaerobic biocell utilizing the Simplot process to be the most potentially effective treatment methods for WPNSTA Yorktown soil.

Based on the results of the bench-scale treatability study, LANTDIV has decided to further the evaluation of the effectiveness of the Simplot technology by conducting a field-scale pilot study at WPNSTA Yorktown. LANTDIV may decide to conduct a pilot study implementing the Tween 80 and molasses bioslurry in the future.

3.0 PILOT STUDY

The Pilot Study will involve the implementation of the SABRE® technology for the remediation of explosives-contaminated soil. This technology operates on the premise of microbiological interactions and contaminant degradation pathways. Appendix A presents additional information pertaining to Simplot's SABRE® technology.

Approximately 500 cubic yards of explosives-contaminated soil will be excavated from Site 7 at WPNSTA Yorktown. The soil will be transported to Site 22 where the Simplot biocell structure will be constructed. Note that the reference to a biocell in the remaining text refers to the structure in which the Simplot SABRE® technology will be implemented.

An overview of the pilot study is presented in Section 3.1 below. Section 3.2 presents a detailed description of the work activities that Baker personnel will be responsible for completing during the field pilot study.

3.1 Overview of the Pilot Study

The Pilot Study using Simplot's SABRE® process will be conducted at Site 22 at WPNSTA Yorktown. The Pilot Study will be implemented in the following steps: 1) Mobilization; 2) Biocell Construction; 3) Excavation of Contaminated Soil; 4) Soil Screening and Fluidizing; 5) Soil Placement into Biocell; 6) Mixing the Biocell; 7) Monitoring the Biocell; and 8) Demobilization. Each of these steps are described in the subsections below. Figure 3-1 presents an overview of the Pilot Study in the form of a flow diagram.

The treatment phase of the Pilot Study will be conducted until confirmatory analytical laboratory results of soil samples collected during the Pilot Study indicate that the concentrations of explosive compounds have met the following treatment goals:

- TNT 30 mg/kg
- RDX 100 mg/kg
- HMX 12,000 mg/kg
- Amino-DNTs 80 mg/kg

- 1,3,5-TNB 12 mg/kg
- 2,4/2,6-DNT (mixture) 25 mg/kg

3.1.1 Mobilization

Mobilization activities will include Simplot transporting their equipment (i.e., gantry system with rail, hydromixer, and fluidizer) to Site 22 at WPNSTA Yorktown. The gantry system will be delivered on flatbeds and will be in six major pieces. Following assembly, the gantry will require a crane to erect it in place.

The remediation contractor, OHM, will mobilize the excavation and construction equipment, vibrating screen, and conveyor. The equipment will be set up in prepared areas (see Figure 3-2). Rented equipment such as pumps, hoses, supply lines, water trucks, suction trucks, high pressure washers, etc. will be brought to the site as needed.

3.1.2 Biocell Construction

The biocell will be constructed in a large flat area at Site 22. The biocell will be an in-ground excavation measuring approximately 86 feet wide by 150 feet long by 7 feet deep. Side slopes will be 1:1. The biocell will be double-lined with an 80-mil high-density polyethylene (HDPE) liner on top, a 6-inch sand layer, and a 60-mil HDPE liner on the bottom. The side slopes of the biocell will be self-supporting without the need for "Geonet" reinforcing. A sand bedding will be laid down to protect the liner. The biocell will be designed to hold 500 cubic yards of soil 2.5 feet deep with 2.5 feet of water above. Figure 3-3 shows a typical cross-section of the biocell.

The soil excavated during the construction of the biocell will be used as berms on the sides of the biocell. The gantry unit which will house the hydromixing system will be mounted on a set of rails running length-wise along the biocell. The rails will be mounted on an 8-inch plate and placed on a concrete anchor trench.

3.1.3 Excavation of Contaminated Soil

Explosives-contaminated soil to be used for the Pilot Study will be excavated from Site 7 at WPNSTA Yorktown. Portions of Site 7 (the drainage way) will be cleared of trees and debris. OHM will excavate soil from Site 7 from within the area identified on Figure 3-4 until approximately 500 cubic yards of soil is obtained. The depth of the excavation will be approximately 3 to 4 feet. Soil may also be excavated immediately adjacent to the shaded area identified on Figure 3-4 if additional soil is needed. It is important to note that physical barriers such as the shallow depth of the groundwater aquifer may limit the depth of excavation at some of the areas at Site 7. Confirmatory soil samples will be collected during the excavation activities and analyzed using EnSys® test kits to estimate the lateral and vertical extent of contamination.

The excavated soil will be loaded into dump trucks and transported to Site 22. Figure 3-5 identifies the potential transport route from Site 7 to Site 22. Following the excavation activities, the disturbed areas at Site 7 will be restored. These areas will be backfilled, regraded, and revegetated.

3.1.4 Soil Screening and Fluidizing

The excavated soil from Site 7 will be transported to the soil screening area at Site 22. The soil will be placed on a vibrating one inch screen so that the soil is screened to a desirable size. Oversized material will be pressure washed and returned to Site 7.

Simplot's fluidizer tank will be positioned under the screen collection hopper. The screened soil will be transferred to the fluidizer with the oversized material decontamination water. Additional water may be mixed with the soil in the fluidizer.

3.1.5 Soil Placement into Biocell

The soil/water mixture will be transferred from the fluidizer to the biocell with the use of a low pressure slurry pump. Approximately 2.5 feet of soil/water mixture will be placed into the biocell,

with an additional 2.5 feet of water added on top of the soil. The biocell will be designed to accommodate up to three feet of soil/water mixture and the additional water.

Chemicals, nutrients, and additives such as pH buffers, a carbon source, and Simplot inoculum will be placed in the biocell to start the degradation process. The carbon source will be a Simplot potato starch by-product from one of their food processing plants.

3.1.6 Mixing the Biocell

The contents of the biocell will be mixed two to three days a week for eight weeks or until the explosive contaminants have met the treatment goals. A hydromixing system suspended from a mobile gantry unit will be implemented for the mixing operations. The mixing system will contain intake suction screens and injection hydro lances. The system works by drawing water from the top of the biocell and pumping it under pressure into the soil without aerating the biocell in the process. The gantry system, which suspends the mixing unit, rides on two rails along the length of the biocell. The gantry system is powered by a small portable generator. At the end of the gantry is a self-powered high pressure pump which drives the mixing system. It may take two workers three to four hours to thoroughly mix the biocell contents. The purpose of the mixing is the mass transfer of contaminants from the soil to the liquid medium, making them more available to the microbial population for degradation.

3.1.7 Monitoring the Biocell

The contents of the biocell will be monitored three times per week during the treatment phase of the Pilot Study. Field parameters will include pH, redox potential, and temperature. A pH target of 7.0 should be easily achieved and maintained once the SABRE® process has begun. A redox potential of less than -200 mV is sufficiently low enough to maximize degradation rates. The target temperature level for the biocell is a minimum 18° C.

In addition to the field parameters, soil/water mixture samples will be collected from the biocell three times per week for laboratory and/or field test kit analysis. The field test kit samples will be analyzed with TNT and RDX EnSys® test kits. These test kits will be able to estimate concentrations for TNT; RDX; HMX; 2,4-DNT; 2,6-DNT; 1,3,5-TNB; and 1,3-dinitrobenzene

(1,3-DNB). The laboratory samples will be analyzed for nitramines/nitroaromatic compounds using SW846-Method 8330. The results from these samples will be evaluated to determine when the soil has reached the treatment goals.

When the laboratory results confirm that the contaminant levels have met the treatment goals, the treated biocell contents will be left in place. Based on other field tests conducted by Simplot on other sites, it is estimated that the treatment goals will be met within eight weeks of operation of the biocell system. The water in the biocell will be allowed to evaporate. If necessary (e.g., if the biocell is to be reused), the treated soil may be transferred in an unlined evaporation/percolation impoundment area constructed at Site 22. This would allow for sequential batches of contaminated soil to be treated.

3.1.8 Demobilization

Demobilization activities will consist of removing and cleaning the equipment used during the Pilot study; removing the staging areas and restoring Site 22; decontaminating the construction equipment; and managing the investigation derived waste (IDW) generated during the sampling activities.

3.2 Baker's Field Work Activities

Baker will provide one field technician on site (part time) during the Pilot Study. The Baker field technician will be responsible for collecting the soil samples; assisting with the biocell mixing operations; and managing the IDW generated during the sampling activities of the Pilot Study. These activities area described below.

3.2.1 Soil Sampling Activities

Soil sampling activities will consist of collecting the confirmatory samples during the excavation activities at Site 7, and collecting the monitoring samples from the biocell during the pilot study. The confirmatory samples will be field tested using EnSys TNT and RDX test kits. The biocell monitoring samples will be field tested and/or sent for laboratory analysis. Details of the sampling activities are described below. Table 3-1 provides a summary of the soil sampling program.

3.2.1.1 Confirmatory Samples from Site 7

The Baker field technician will collect ten discrete soil samples from the excavation at Site 7. The exact location of the samples will be determined in the field and recorded in a field log book. Approximately six of the ten samples will be collected from the bottom of the excavation to aid in determining the vertical extent of explosive contamination. The other four samples will be collected along the sides of the excavation to aid in determining the horizontal extent of explosive contamination. The samples will be collected over a one foot depth at each location. The samples will be labeled PS7-S01 through PS7-S10.

The samples will be collected using a stainless steel hand auger or equivalent. The Master FSP, Sections 3.8 and 3.9 describe soil sampling procedures which may be used to collect the samples.

The Baker technician will field test the confirmatory samples on site at the Baker trailer using the EnSys test kits for TNT and RDX analysis. The results will be recorded in a field log book with time, date, and sample number identified. Information pertaining to the EnSys test kits is included in Appendix B.

3.2.1.2 Biocell Monitoring Soil Samples (EnSys Test Kits)

The Baker field technician will collect four composite soil samples from the biocell three days per week for a total of 12 samples per week. Each composite sample will consist of soil collected from four or five different areas of the biocell. It is assumed that the treatment phase of the Pilot Study will be conducted for eight weeks, therefore, 96 samples will be collected over the course of the study. The samples will be labeled PS22-S01 through PS22-S96.

The composite samples will be collected from the overhead platform of the gantry system. The samples will be collected using a stainless steel hand auger or equivalent. The Master FSP, Sections 3.8 and 3.9 describe other soil sampling procedures which may be used to collect the soil samples.

These samples will be field tested on site at the Baker trailer using EnSys test kits for TNT and RDX analysis. As previously mentioned, these kits will be able to estimate concentrations for several other explosive compounds. The results will be recorded in a field log book with time, date, and

sample number identified. In addition to the TNT and RDX analysis, soil samples will be field analyzed for pH, redox potential, and temperature. These results will be recorded in the field log book.

3.2.1.3 Biocell Monitoring Soil Samples (Laboratory Analysis)

The Baker field technician will send two out of every four composite soil samples collected for EnSys test kit analysis for off-site laboratory confirmatory analysis. Therefore, six soil samples per week will be sent to the off-site laboratory. Based on an eight-week treatment phase, 48 composite soil samples will be sent to the laboratory. The samples will be labeled to correspond to the EnSys test kit samples with an -01 extension added to the label. For example, if the EnSys composite sample PS22-S03 is to be sent to the off-site laboratory, the sample will be labeled as PS22-S03-01.

The Baker field technician will also collect and send the appropriate number of quality control (QC) samples to the laboratory (Table 3-1).

The samples will be sent to a Naval Energy and Environmental Support Activity (NEESA)-approved laboratory and analyzed for nitramine/nitroaromatics using SW846-Method 8330. A seven-day turnaround time will be requested from the laboratory. The data will be Level C since there area no Contract Laboratory Program (CLP) procedures established for explosives. The analytical method, detection limits, and quality assurance/quality control (QA/QC) procedures area described in the Master QAPP (Section 6.0).

Data validation will be performed on the laboratory samples by an independent data validation firm. The procedures for validation will follow the appropriate Level D guidelines listed in the NEESA guidance document (NEESA 20.2-047B). Further details concerning data validation area presented in the Master QAPP (Section 7.0).

3.2.2 Soil Mixing Activities

The Baker field technician will assist Simplot personnel with the hydromixing system. The mixing activities will be conducted three times per week (the same days that the monitoring sampling will be conducted). It will take approximately three to four hours to thoroughly mix the biocell contents.

The Baker field technician will also assist the Simplot representative with the maintenance of the hydromixer during these days.

3.2.3 IDW Management

Baker will be responsible for the IDW generated during the sampling activities of the Pilot Study which will include waste acetone from the EnSys test kits, disposable sampling equipment, personal protective equipment (PPE) such as gloves, and Tyvek, and portions of the soil samples not used in the analyses. The waste acetone will be stored in a 55-gallon drum staged at Baker's field trailer. The drum will be placed on a wooden pallet and covered with a tarp. This aqueous IDW will be handled as hazardous waste and will be disposed of accordingly. The drum will be labeled as noted in the Master FSP, Section 3.26.3.

The disposable sampling equipment and PPE will be double bagged and placed in the refuse dumpster staged at Baker's field trailer.

The remaining portions of the soil samples not used for analysis will be returned to the biocell.

Note that decontamination water generated by OHM will be placed directly into the biocell.

4.0 PROJECT MANAGEMENT AND RESPONSIBILITIES

The success of the Pilot Study will involve the coordination of three separate firms with separate responsibilities: Baker, Simplot, and OHM. The proposed management and staffing for the Pilot Study is depicted on Figure 4-1. The primary participants for the project will be:

LANTDIV

- Mr. Richard N. Stryker, Navy Technical Representative

WPNSTA Yorktown

- Mr. Jeffrey Harlow, Environmental Protection Specialist
- Mr. Bernard Setterholm, Environmental Protection Specialist

Baker Environmental, Inc. (LANTDIV's CLEAN Contractor)

- Ms. Tammi Halapin, Project Manager
- Mr. Richard Hoff, Activity Coordinator
- Ms. Coreen Casadei, P.E., Project Engineer
- Field Technician (to be named later)

Simplot (Subcontractor to Baker)

- Mr. Tom Yergovich, Manager SABRE® Technology

OHM (LANTDIV's Remediation Contractor)

- Mr. Mark Kravetz, OHM Project Manager
- Mr. Dave Leadenham

United States Environmental Protection Agency (USEPA), Region III

- Mr. Robert Thomson, P.E., USEPA Remedial Project Manager

Virginia Department of Environmental Quality (VDEQ)

- Mr. Stephen Mihalko, Federal Facilities Project Officer

The primary responsibilities of Baker, Simplot, and OHM area listed below.

Baker's responsibilities will include:

- Provide the project management of the Pilot Study
- Provide technical/financial oversight of Simplot (subcontractor)
- Serve as liaison between Simplot, LANTDIV, WPNSTA Yorktown, and the regulatory representatives
- Collect confirmatory soil samples at Site 7 during excavation activities
- Communicate the project status and preliminary test results to LANTDIV, as necessary
- Provide part-time assistance to Simplot with the operation of the hydromixing system
- Collect the biocell monitoring samples including pH, redox potential, temperature, and soil samples for explosive analysis (both for field test kits and for off-site laboratory analysis)
- Manage the IDW generated during the sampling activities of the Pilot Study

Simplot's responsibilities will include:

- Provide the hydromixing system and pumps; the gantry rail system; the fluidizing equipment and pumps, the biocell additives, and the Simplot proprietary innoculum
- Provide approval and supervision of the implementation of the SABRE® technology
- Provide oversight with respect to technology transfer and quality assurance
- Provide recommendations on the biocell construction and loading
- Supervise the soil treatment process

OHM's responsibilities will include:

- Provide excavation and construction equipment
- Provide the soil screening system (vibrating screen) and conveyor
- Provide any other miscellaneous equipment and supplies needed for the Pilot Study
- Provide the materials for and construct the biocell
- Construct the concrete anchor trench for the gantry rails
- Install the gantry rails
- Assemble and erect the gantry system

- Clear the area(s) to be excavated at Site 7 and the Pilot Study areas at Site 22 as needed, and provide all necessary erosion prevention controls

- Excavate 500 cubic yards of soil from Site 7 and transport it to the soil screening system at Site 22

- Excavate and stockpile soil from Site 22 taken from the area in which the biocell will be constructed

- Restore the disturbed areas at Site 7

- Operate the soil screening system and stage/manage the oversized materials (return it back to Site 7)

- Properly decontaminate appropriate equipment

- Restore all appropriate areas at Sites 7 and 22

5.0 SCHEDULE

The proposed schedule for completing the Pilot Study activities is presented on Figure 5-1. Construction of the biocell is anticipated to start in August 1996. The treatment phase of the Pilot Study is anticipated to start in the middle of September 1996 and continue through the beginning of November 1996 (eight week duration). A two week final demobilization period has been assumed. Following the completion of the field portion of the Pilot Study, a Pilot Study report will be prepared to provide a presentation and evaluation of the Pilot Study monitoring results.

6.0 REFERENCES

Baker Environmental, Inc. (Baker). 1996. Draft Round Two Remedial Investigation and Baseline Risk Assessment - Sites 6 and 7, Naval Weapons Station Yorktown, Yorktown, Virginia. Contract Task Order 0319. Prepared for the Department of the Navy, Atlantic Division Naval Facilities Engineering Command, Norfolk, Virginia. June 1996.

Baker. 1994a. Final Master Project Plans, Naval Weapons Station, Yorktown, Virginia. Contract Task Order 0209. Prepared for the Department of the Navy, Atlantic Division Naval Facilities Engineering Command, Norfolk, Virginia. June 1994.

Baker. 1994b. Final Work Plan Sites 6, 7, 12, Site Screening Area 16 and Background, Naval Weapons Station Yorktown, Yorktown, Virginia. Contract Task Order 0209. Prepared for the Department of the Navy, Atlantic Division Naval Facilities Engineering Command, Norfolk, Virginia. June 1994.

United States Army Corps of Engineers Waterways Experiment Station (WES). 1995. Technical Approach to the Bench Scale Treatability Studies on Explosives Contaminated Soils from the Yorktown Naval Weapons Station " Final Treatability Study Work Plan" . Prepared for the Department of the Navy, Atlantic Division Naval Facilities Engineering Command, Norfolk, Virginia. May 1995.

TABLES

TABLE 2-1

SUMMARY OF MAXIMUM EXPLOSIVE COMPOUND CONCENTRATIONS DETECTED IN SITE 7 - SOIL AND SEDIMENT SAMPLES NAVAL WEAPONS STATION YORKTOWN YORKTOWN, VIRGINIA

	Maximum Detected Concentration (µg/kg)		
	Round One RI	Round Two RI	Treatability Study Characterization Sampling
Detected Explosive Compounds	Soil and Sediment	Soil and Sediment	Sediment
HMX	ND	ND	3,200,000
RDX	ND	ND	14,000,000
2,4,6-TNT	ND	ND	40,000,000
Amino-Dinitrotoluene	ND	ND	84,700

Notes:

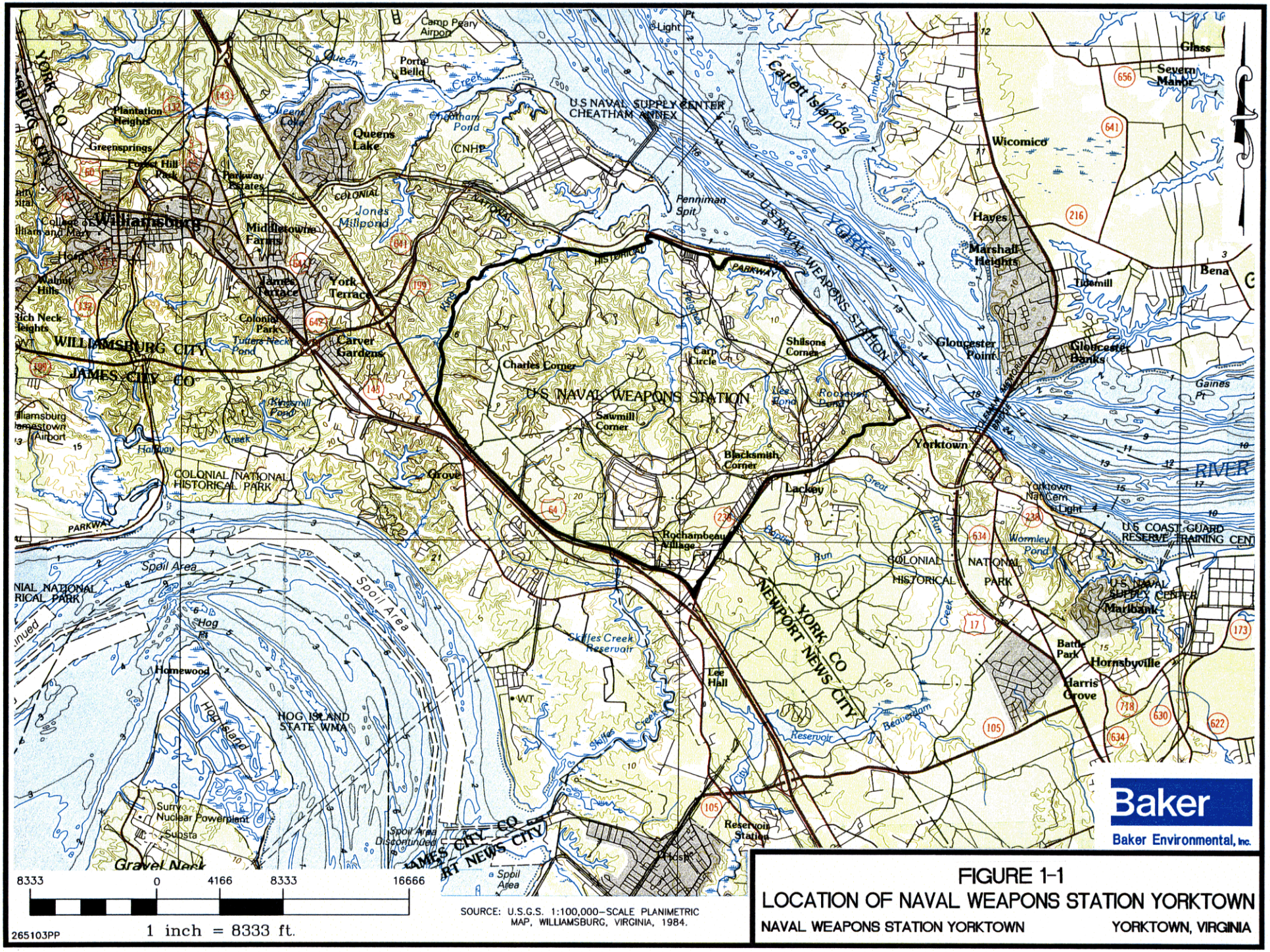
ND = Not Detected

TABLE 3-1

PILOT STUDY MONITORING PROGRAM SUMMARY
NAVAL WEAPONS STATION YORKTOWN
YORKTOWN, VIRGINIA

Sample Type	Sample Frequency	Analytical Parameters	Quality Control Samples			
			Number of Duplicates	Number of MS/MSDs	Number of Rinsate Blanks	Number of Field Blanks
Confirmatory Soil from Site 7 - Field Tested	During Site 7 Excavation Activities (10 discrete samples)	TNT and RDX (EnSys Test Kits)	Not Applicable	Not Applicable	Not Applicable	Not Applicable
Biocell Soil - Field Tested	4 composite samples collected 3 times per week (96 samples)	TNT and RDX (EnSys Test Kits); pH; redox potential; temperature	Not Applicable	Not Applicable	Not Applicable	Not Applicable
Biocell Soil - Laboratory Tested	2 composite samples collected 3 times per week (48 samples)	Nitroaromatics per Method 8330 (7-day turn around requested)	5 (1 out of every 10 samples)	3 (1 out of every 20 samples)	1	3

FIGURES



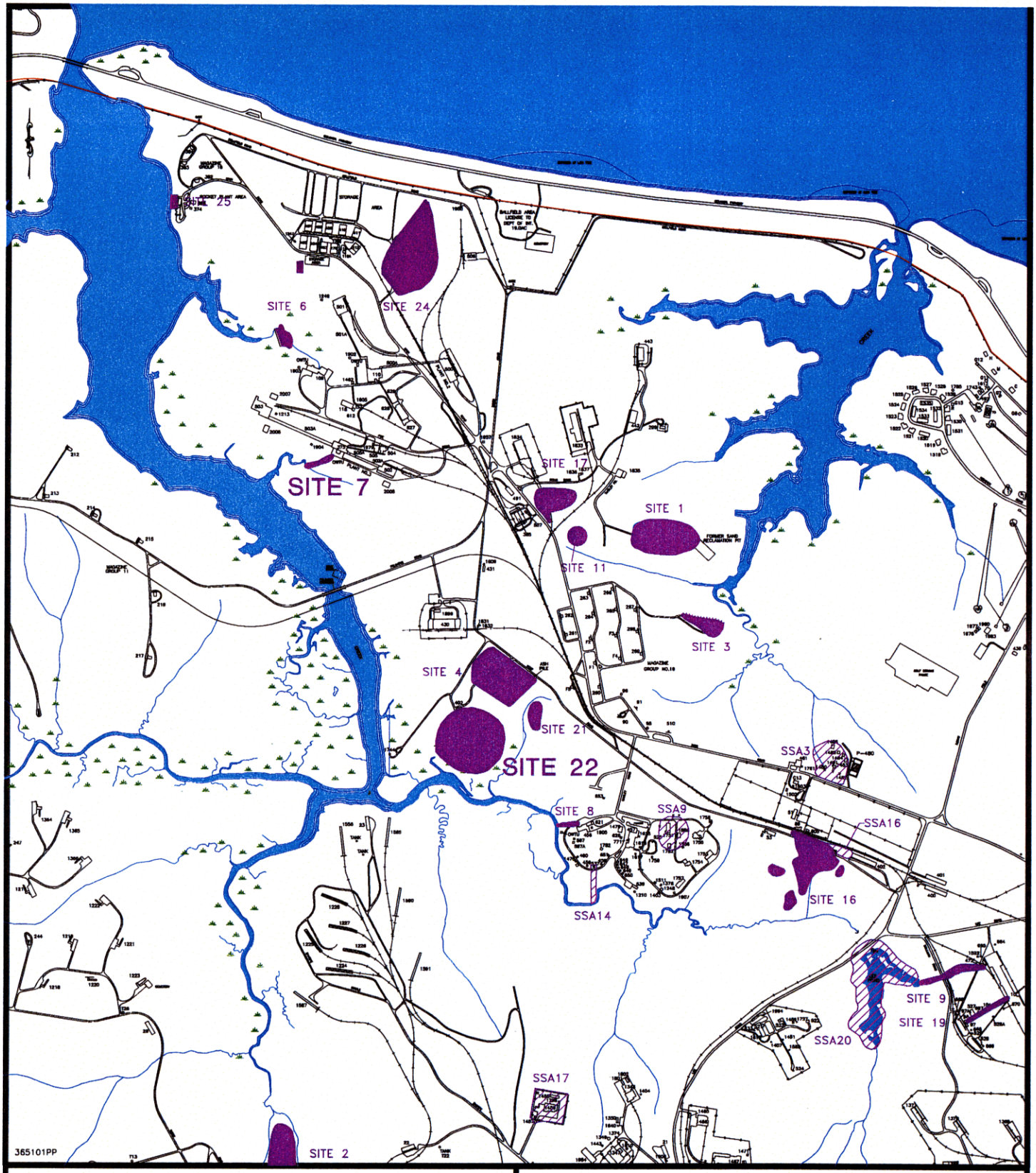
SOURCE: U.S.G.S. 1:100,000–SCALE PLANIMETRIC MAP, WILLIAMSBURG, VIRGINIA, 1984.

Baker

Baker Environmental, Inc.

FIGURE 1-1
LOCATION OF NAVAL WEAPONS STATION YORKTOWN

NAVAL WEAPONS STATION YORKTOWN — YORKTOWN, VIRGINIA



LEGEND

- WPNSTA YORKTOWN BOUNDARY
- DRAINAGE
- EDGE OF PAVEMENT
- MARSH
- RAILROAD
- FENCE
- STRUCTURE
- REMEDIAL INVESTIGATION SITE
- SITE SCREENING AREA (AREAL EXTENT APPROXIMATE)

800 0 400 800
GRAPHIC SCALE IN FEET

SOURCE: NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

FIGURE 2-1
LOCATION OF SITES 7, AND 22

NAVAL WEAPONS STATION YORKTOWN
YORKTOWN, VIRGINIA

Figure 2-2

Fate of TNT in Anaerobic and Aerated Biocell Reactors

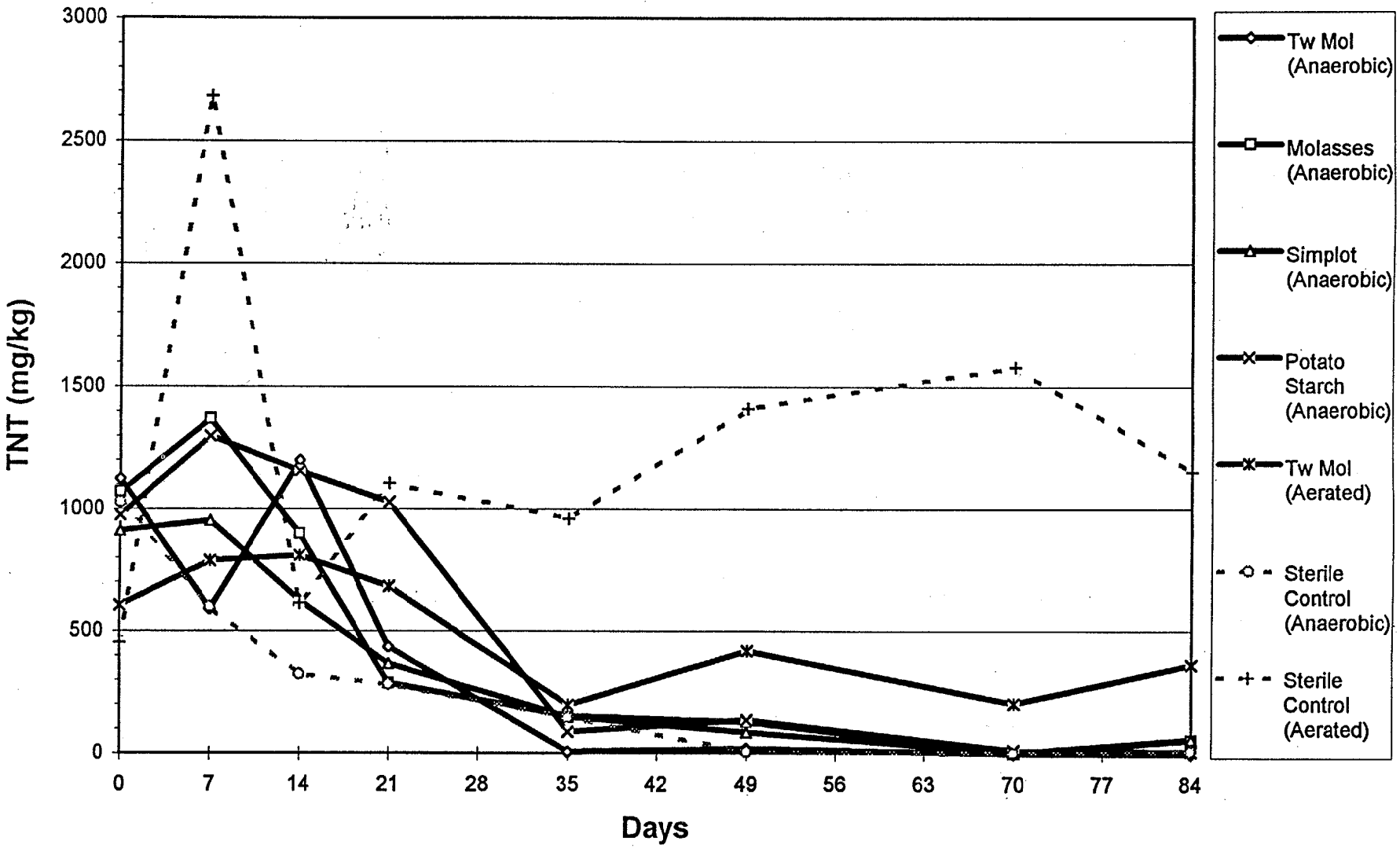
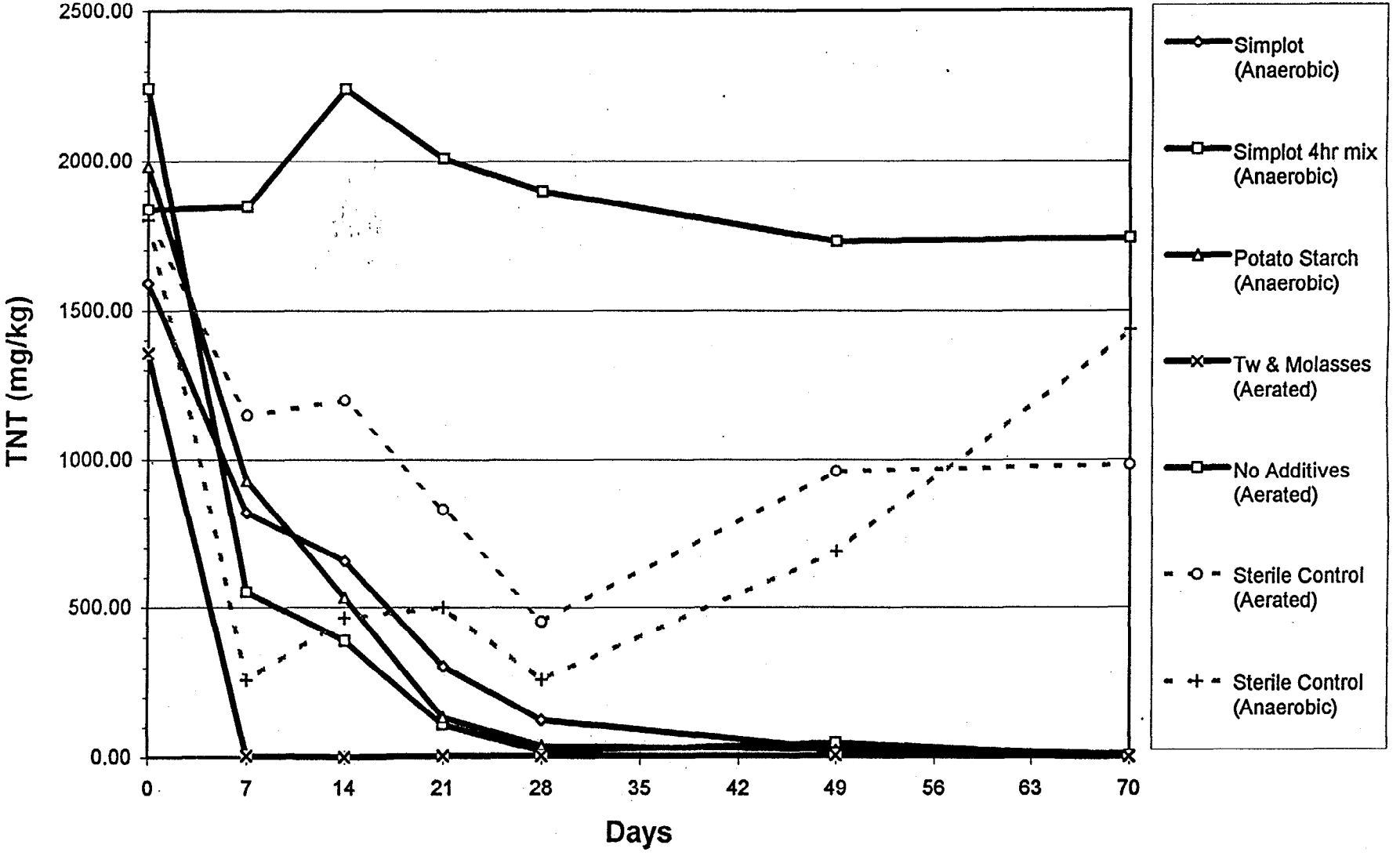
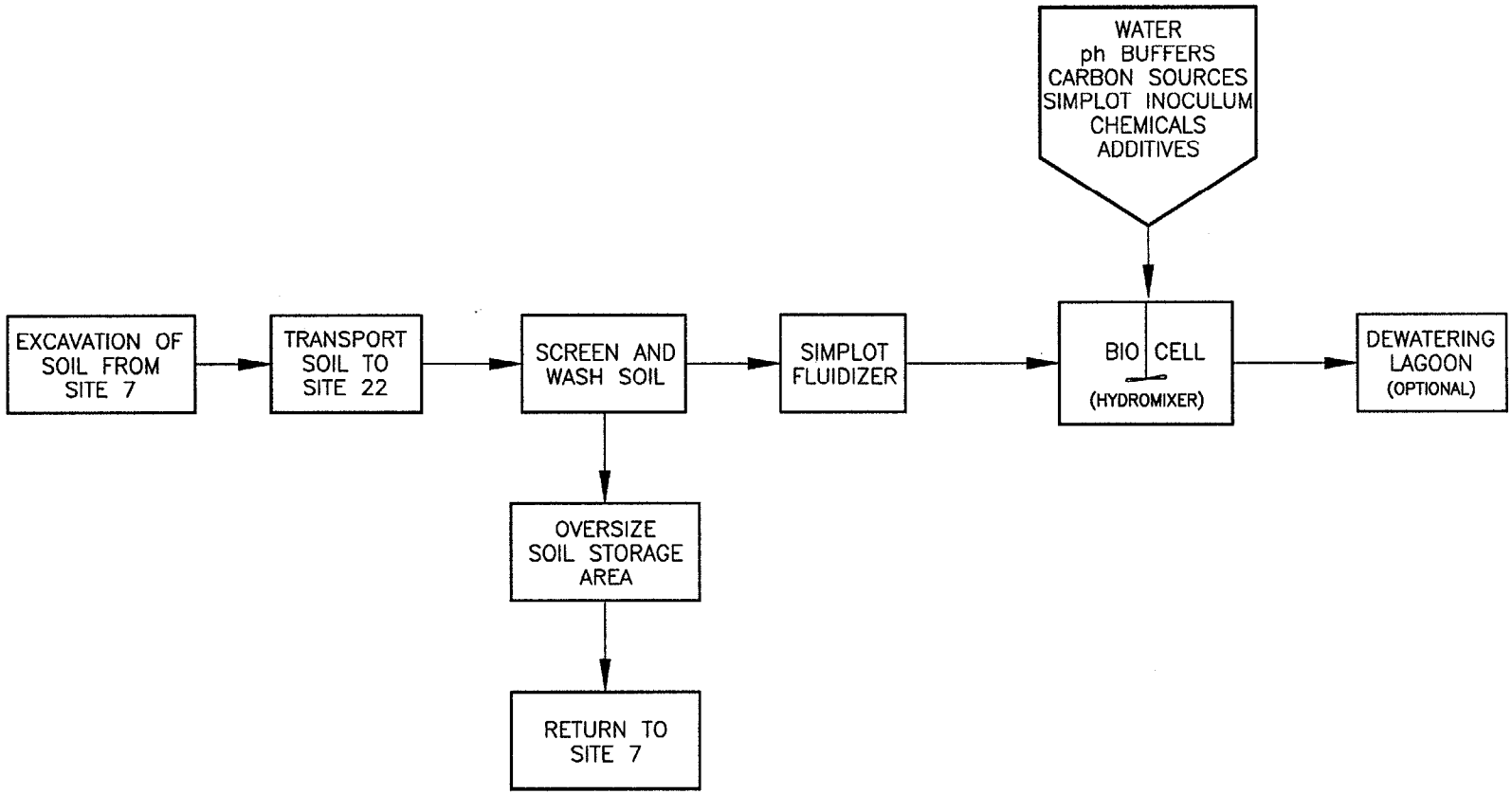


Figure 2-3

Fate of TNT in Anaerobic and Aerated Bioslurry Reactors





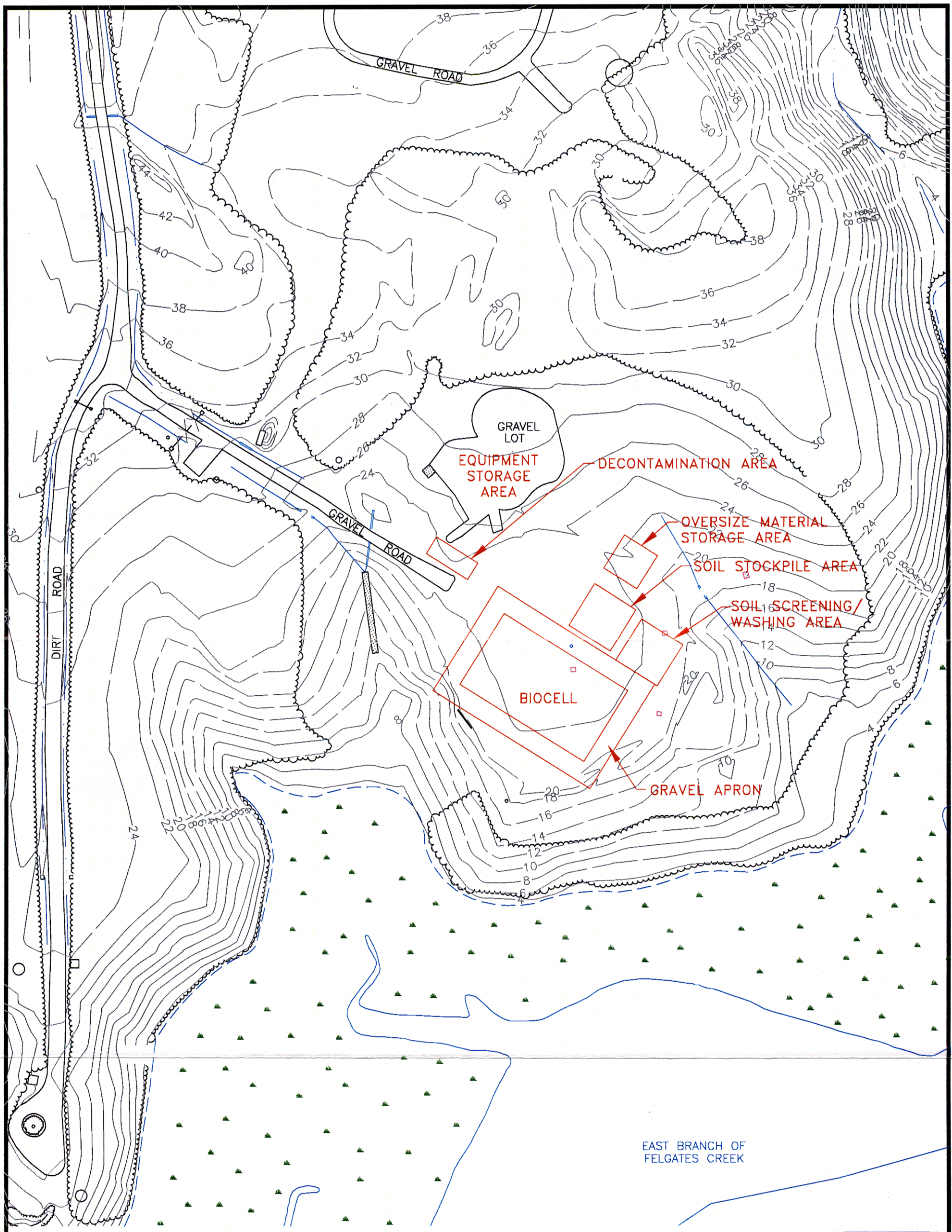
Baker

Baker Environmental, Inc.

FIGURE 3-1
PROCESS FLOW DIAGRAM

NAVAL WEAPONS STATION YORKTOWN YORKTOWN, VIRGINIA

365107PP



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Baker Environmental, Inc.

LEGEND

- MARSH
- RIPRAP
- CONCRETE CULVERT
- INTERMITTANT DRAINAGE
- DEBRIS AREA
- TREE LINE

NOTE: EXACT LOCATIONS OF ALL AREAS WILL BE DETERMINED IN THE FIELD.

SOURCE: MILLER–STEPHENSON & ASSOCIATES, MAY 1996.

FIGURE 3-2
TREATMENT SYSTEM LAYOUT

NAVAL WEAPONS STATION YORKTOWN YORKTOWN, VIRGINIA

365108PP

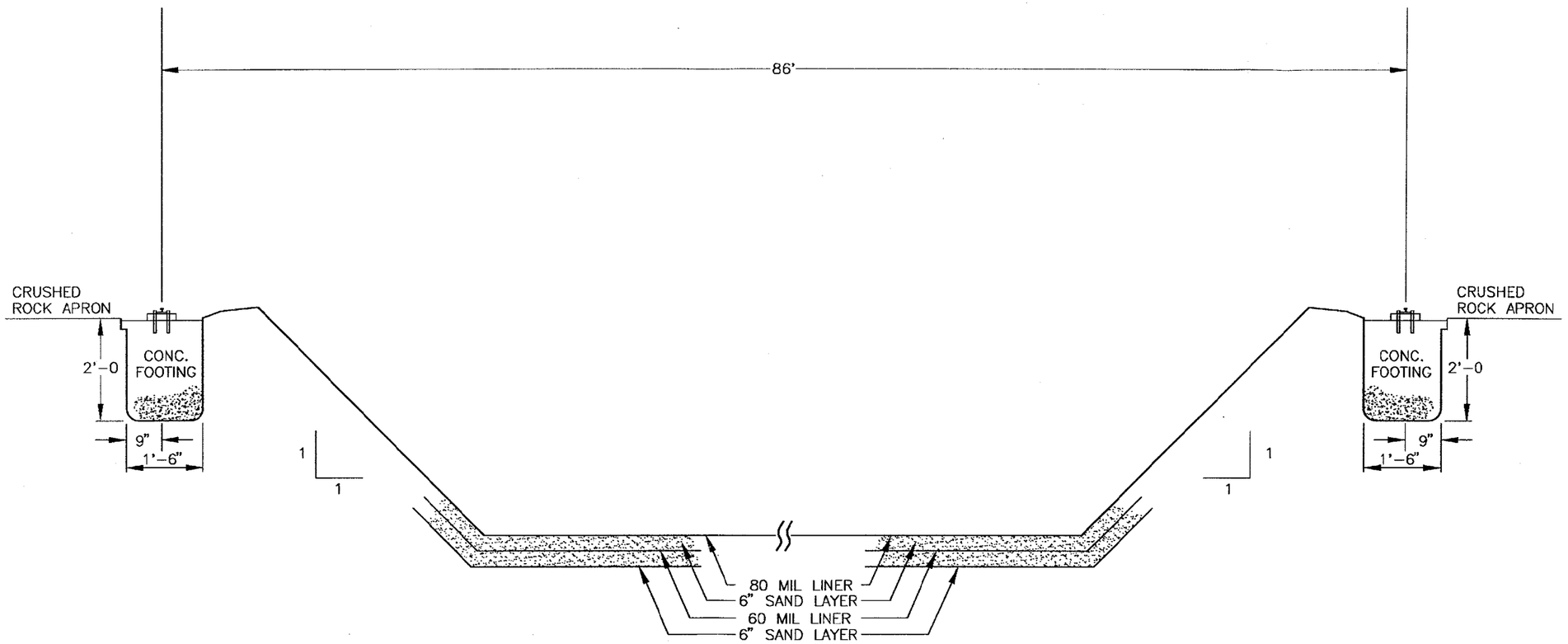

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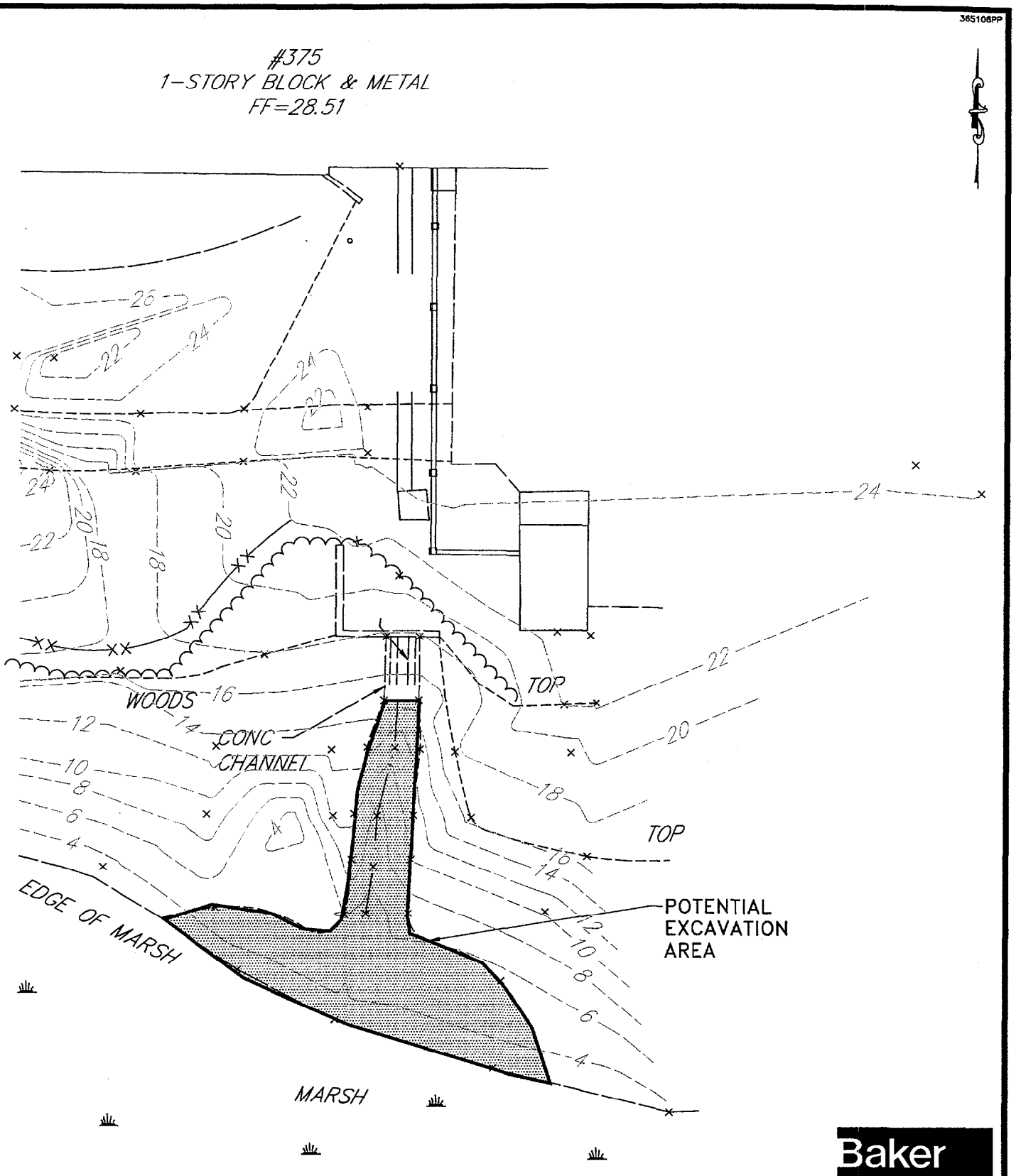
FIGURE 3-3
TYPICAL BIOCELL
CROSS-SECTION

NAVAL WEAPONS STATION YORKTOWN YORKTOWN, VIRGINIA

00870403Z



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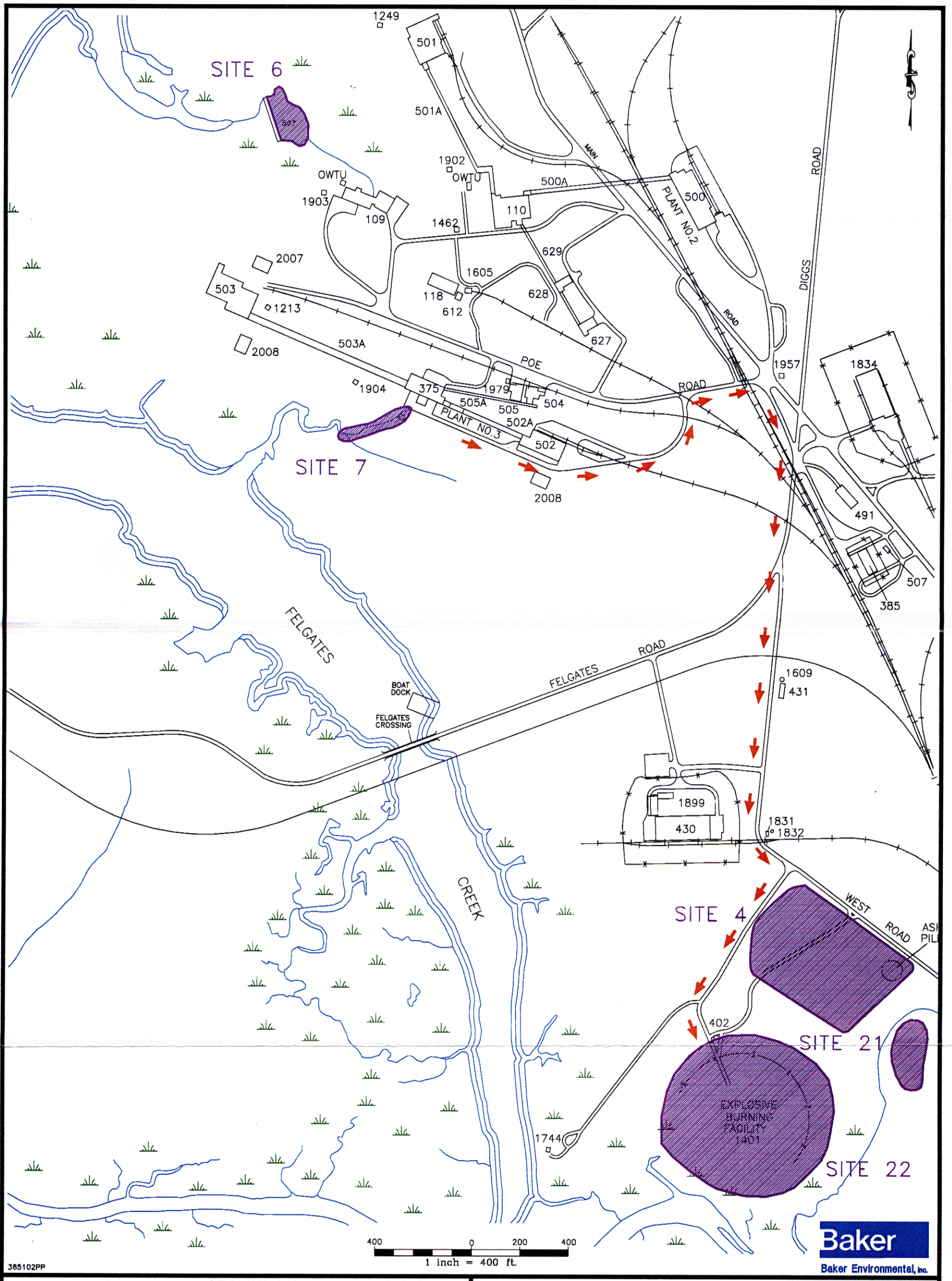
Baker Environmental, Inc.

SOURCE: MILLER-STEPHENSON & ASSOC., JULY 1996

FIGURE 3-4
POTENTIAL EXCAVATION AREA
AT SITE 7
NAVAL WEAPONS STATION YORKTOWN
YORKTOWN, VIRGINIA



LEGEND

POTENTIAL TRANSPORTATION ROUTES

SOURCE: LANTDIV, OCT. 1991

FIGURE 3-5
TRANSPORTATION ROUTES FROM
SITE 7 TO SITE 22

NAVAL WEAPONS STATION YORKTOWN YORKTOWN, VIRGINIA

00870404X

FIGURE 4-1

PROJECT ORGANIZATION
PILOT SCALE TREATABILITY STUDY
NAVAL WEAPONS STATION YORKTOWN
YORKTOWN, VIRGINIA

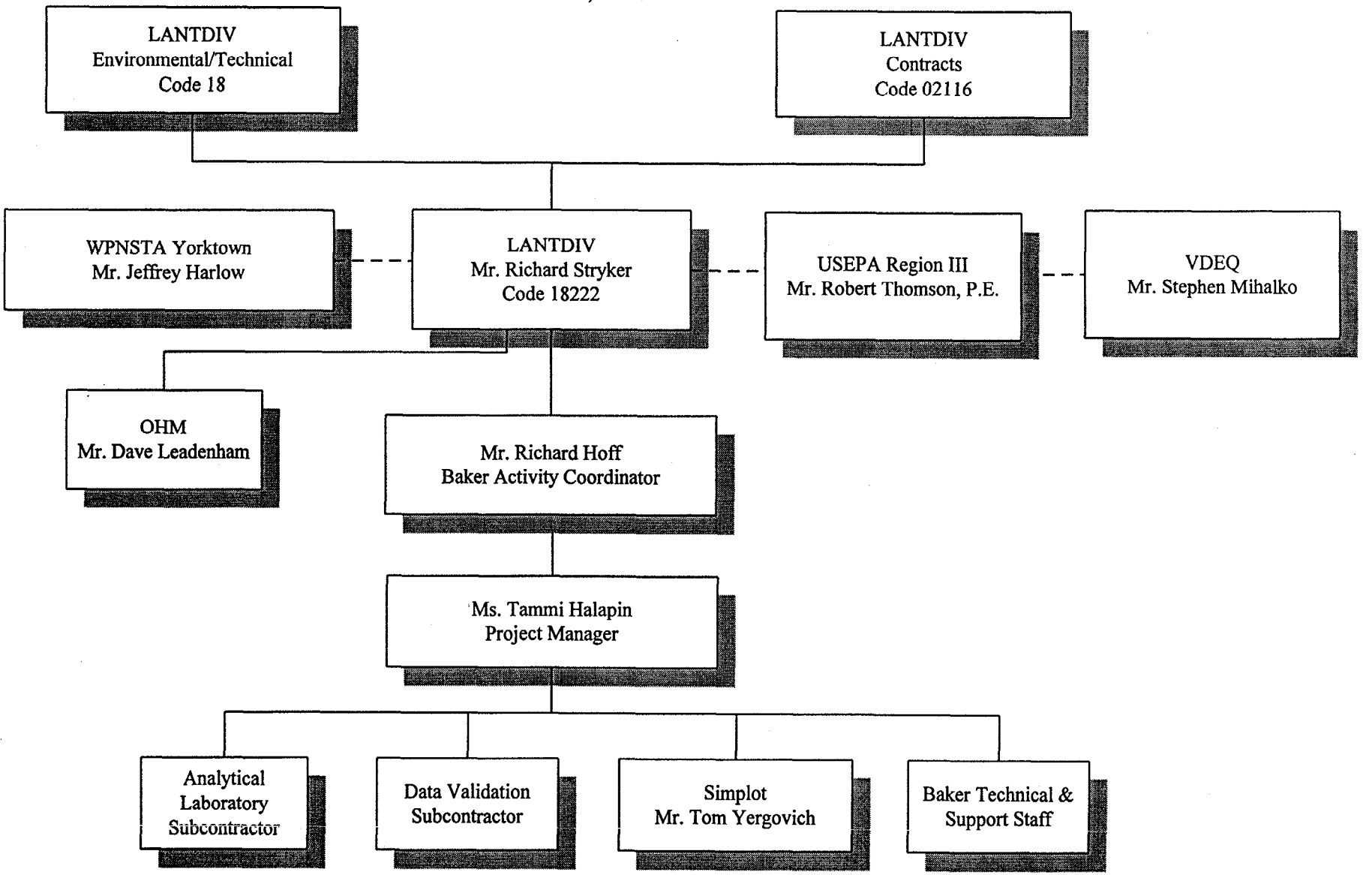
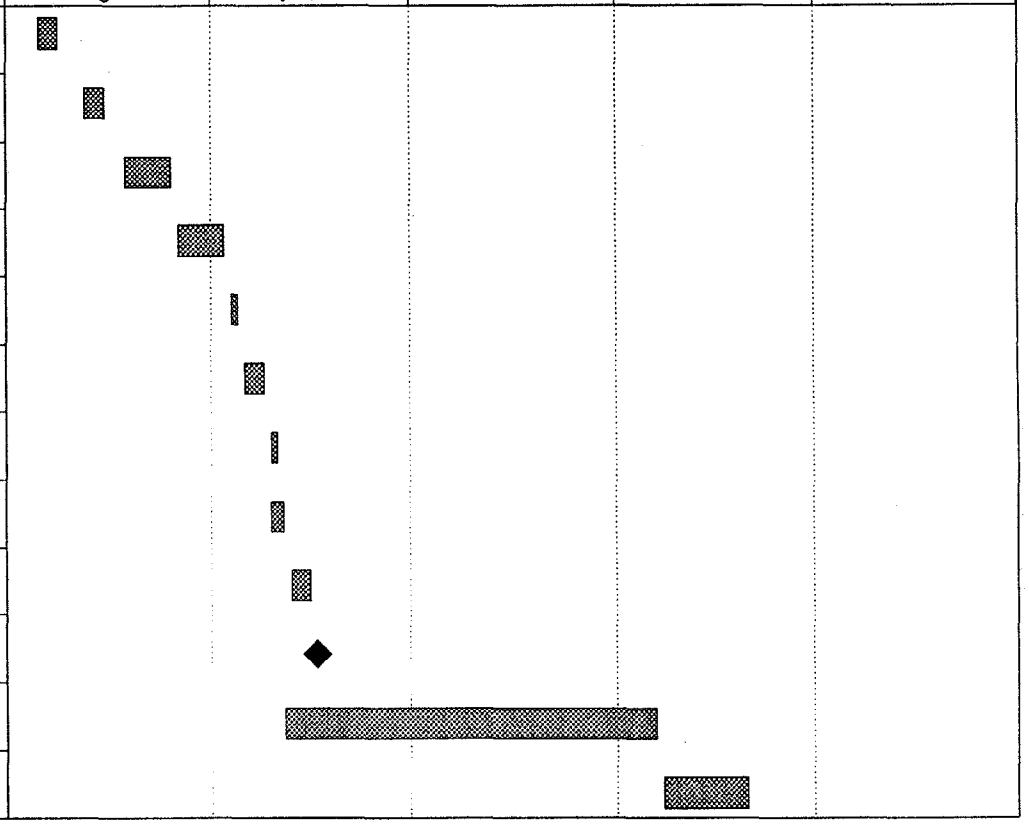


Figure 5 - 1
Pilot Study Schedule
Naval Weapons Station Yorktown, Yorktown, Virginia

Task Name	Duration	Start	Finish
Mobilization/Setup	3ed	8/6/96	8/9/96
Excavate Biocell	3ed	8/13/96	8/16/96
Line Biocell	7ed	8/19/96	8/26/96
Footings and Anchor Bolts	7ed	8/27/96	9/3/96
Grout Rail	1ed	9/4/96	9/5/96
Erect Gantry	3ed	9/6/96	9/9/96
Excavate Soil at Site 7	1ed	9/10/96	9/11/96
Screen and Load Soil	2ed	9/10/96	9/12/96
Restore Site 7	3ed	9/13/96	9/16/96
Demobilization of Construction Equipment	0ed	9/17/96	9/17/96
Biocell Operation	56ed	9/12/96	11/7/96
Biocell Demobilization	13ed	11/8/96	11/21/96



Project: CTO-0365
Date: 7/31/96

APPENDIX A
SIMPLOT SABRE® TECHNOLOGY INFORMATION

Simplot
J. R. SIMPLOT COMPANY
MINERALS & CHEMICAL GROUP

SABRE™ Technology
3395 Joshua Woods Place
Concord, CA 94518
(510) 671-9555

TECHNOLOGY OVERVIEW:
THE *SABRE*™ PROCESS

SIMPLOT ANAEROBIC BIOLOGICAL REMEDIATION OF NITROAROMATIC-CONTAMINATED SOIL

BACKGROUND

Through a joint research effort with the University of Idaho, the J. R. Simplot Company (Simplot) has developed a technology for remediating nitroaromatic compounds in soils. This bioremediation technology, named the SABRE™ (Simplot Anaerobic Biological Remediation) process treats contaminated soil with naturally selected microorganisms. Initial studies and method development were performed by Drs. Ron and Don Crawford at the University of Idaho with funding provided by the J. R. Simplot Company. In these studies, the compound of interest was dinoseb (2-*sec*-butyl-4,6-dinitrophenol), a herbicide used on potatoes, legumes, and many other crops before being banned by the U.S. Environmental Protection Agency in 1986. This technology results in the destruction of the nitroaromatic compound to molecules such as acetate and other organic acids which are easily metabolized by common soil microorganisms. Further research has also demonstrated the application of this technology on similar nitroaromatic compounds such as TNT (2,4,6-trinitrotoluene) and other explosive compounds such as RDX (hexahydro-1,3,5-trinitro-triazine) and HMX (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetraazocine).

U. S. and foreign patent applications have been filed for the SABRE™ process by the Idaho Research Foundation Inc. (IRF). The U. S. patent was issued by IRF in February 1995. The J. R. Simplot Company owns the exclusive world-wide license to use this technology.

The SABRE™ Process was accepted into the US EPA's Superfund Innovative Technology Evaluation (SITE) Emerging Technology Program in January 1990 and the SITE Demonstration Program in 1992. The SITE Demonstration for dinoseb was conducted at a site in Ellensburg, Washington in the summer of 1993. The sampling and analyses work for this field trial was performed by Science Applications International Corp. (SAIC), an independent contractor for the EPA. The SITE Demonstration for TNT took place at a Department of Defense (DOD) facility in Weldon Spring, Missouri in the fall and winter of 1993. Testing was completed in early 1994 and the final report is also now available. A final report on this demonstration is now available, entitled *"J. R. Simplot Ex-Situ Bioremediation Technology for Treatment of TNT-Contaminated Soils: Innovative Technology Evaluation Report"*

METHODOLOGY

The natural biological degradation of nitroaromatic compounds under either aerobic or anaerobic conditions begins with the reductive transformation of the nitro (NO_2) groups to amino (NH_2) groups. The advantage of the SABRE™ process is the creation of favorable environmental conditions for maintaining the nitroaromatic compounds in a form that is available to microorganisms for complete degradation. The approach is to accelerate the initial reductive step by rapidly creating anaerobic conditions. When oxygen is excluded, formation of hydroxylamines is not favored, thus minimizing the possibility of polymerization and leaving the amino intermediates available for further degradation.

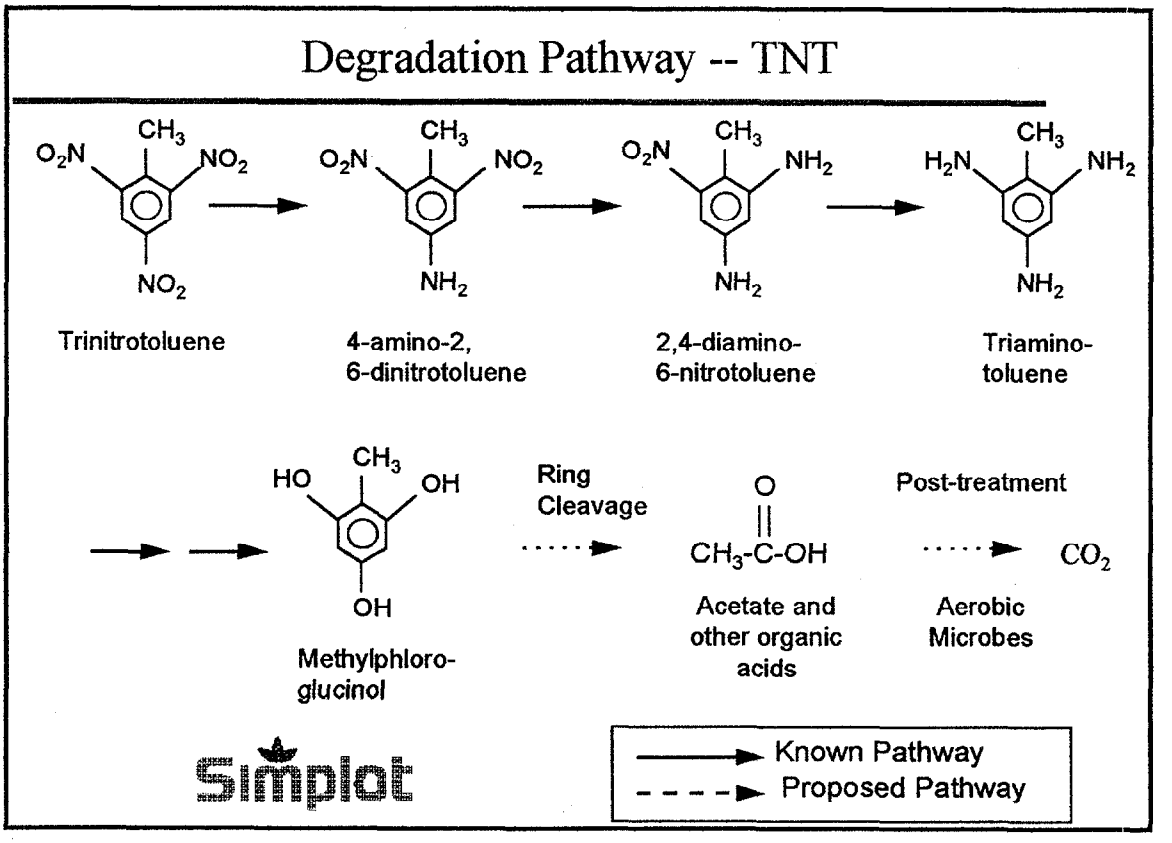
The amino groups can then react with oxygen to form very reactive and toxic hydroxylamines (NHOH). These compounds combine with other hydroxylamines, humic materials, and soil organic matter to form a random polymer that can bind tightly to soil constituents. Under certain soil conditions this polymer could be broken down and release the original hydroxylamines to the environment.

Complete destruction of the aromatic ring is accomplished by using naturally occurring anaerobic soil microorganisms that have been specially selected for their ability to degrade nitroaromatic compounds under controlled environmental conditions.

To establish anaerobic conditions quickly the soil is flooded with a pH buffered water to minimize oxygen diffusion into the soil. The nitroaromatic-degrading microbial consortium is also added to the reactors. To create the highly reducing (low redox potential) conditions required for the microorganisms to thrive, a carbon source is added to the soil/water slurry. Aerobic bacteria in the water and soil consume the carbon source which depletes the remaining oxygen and lowers the redox potential of the system. When the redox potential is sufficiently low (approximately -200 mV), the specially selected anaerobic consortium becomes active. Utilizing the remaining carbon source, the consortium degrades the target nitroaromatic compounds.

The treatment procedures for soils contaminated by dinoseb, or TNT are basically the same. Both of the nitroaromatic compounds have similar degradation pathways.

The degradation pathway for TNT is illustrated in the following diagram.



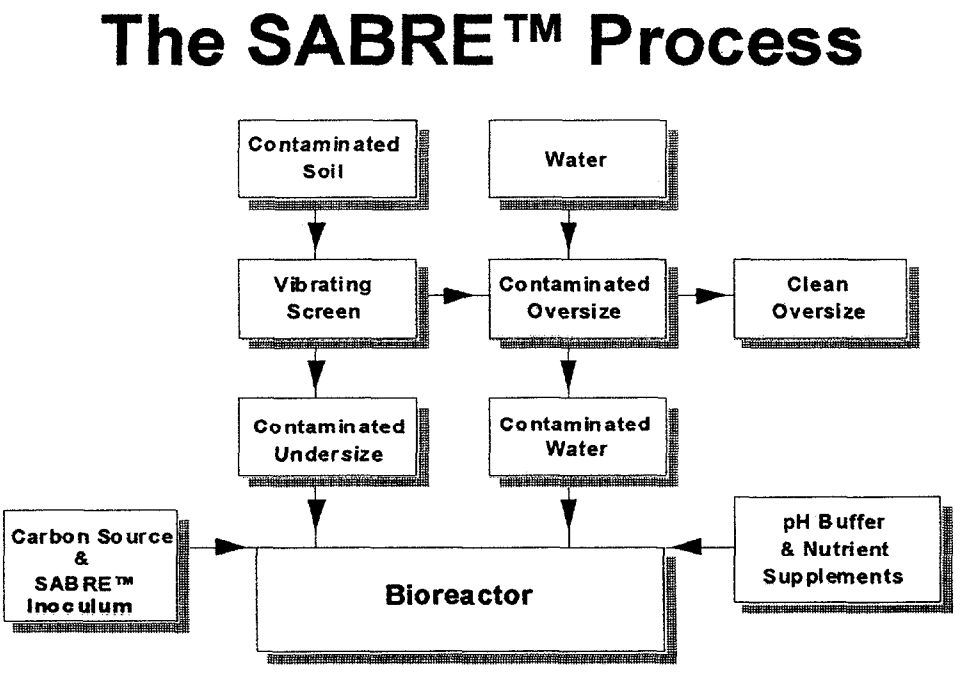
PROCESS

The SABRE™ process employs a bioreactor equipped for monitoring and periodic mixing. Excavation, screening, homogenization and possibly specialized separation equipment are required to prepare contaminated soils prior to introduction into the biocells. All equipment selected for final remediation is portable, modular and readily adaptable in the field. The soil is first screened to desired size, usually to one inch. Oversized material is water washed and undersized material is placed in the bioreactor with the oversize wash water. The SABRE™ process is described in the illustration below.

For small commercial remediation sites, small portable bioreactors can be utilized. At larger sites, bio-reactors or open lined in-ground biocells can be utilized. When operated in the batch mode, each batch receives the specially-selected SABRE™ inoculum, which decreases the amount of time needed to degrade the nitroaromatics. During the treatment phase, personnel are not required to be on site full time.

The SABRE™ monortoring parameters include pH, redox potential, temperature and contaminate levels. Field demonstrations verify that once the SABRE™ process was begun, pH targets were easily achieved and maintained. A redox potential of less than -200 mV is sufficiently low to maximize degradation rates. During bench scale treatability studies, it was determined that the optimum reaction temperature was 35 to 37°C. Field results show that a reactor temperature as low as 18°C could sustain degradative activity.

During periodic agitation of the reactor, the solid phase is recontacted with the liquid in a manner preventing aeration of the liquid. Treatability studies and field trials have shown that these semi-static systems will achieve acceptable results when soil, water, and carbon sources are well mixed during loading of the bioreactor.



PROJECT EXPERIENCE

At the Weldon Spring demonstration, (for the EPA SITE Program), TNT concentrations of 1500 ppm were reduced to an average concentration less than 10 ppm, which represents a reduction of 99.4%. The TNT toxic intermediates were also eliminated using the SABRE™ process.

At the Ellensburg SITE demonstration, , (for the EPA SITE Program), concentrations of dinoseb were reduced by greater than 99.9%. The SABRE™ process reduced the concentration to below the analytical detection limit of 15 ppb within 23 days. All analytical work was performed by an independent EPA contractor. The remediated soil met treatment requirements of the Washington Department of Ecology and approval was obtained to return the treated soil to an uncontaminated area near the site.

For the Nebraska Ordnance Plant, Mead Nebraska, a treatability study was performed for the Army Corps of Engineers, in which the SABRE™ Process was compared to composting and white rot fungus for treating soil contaminated with high levels of TNT and RDX. Upon completion of the study, SABRE™ was the only technology able to attain the treatment goals for all compounds of interest. Initial concentrations of TNT and RDX were 1700 and 2400 mg/kg, respectively.
In a treatability study performed for the Army Corps of Engineers, the SABRE™ Process was compared to composting and white rot fungus for treating soil contaminated with high levels of TNT and RDX. Upon completion of the study, SABRE™ was the only technology able to attain the treatment goals for all compounds of interest.

At Bangor Naval Submarine Base in Washington State a pilot scale field remediation of soils contaminated with TNT, RDX, and DNT was performed in December 1994. Two soils with different types of contamination were treated in double-lined in-ground reactors. This demonstration also utilized our innovative mixing system and tested the process under adverse weather conditions. Treatment goals for both soils were achieved.

A demonstration for dinoseb contaminated soil was completed in September 1994 under the California Technology Certification Program at Reedley California. Contaminated soil at Reedley was reduced to below the analytical detection limit from starting concentrations greater than 600 ppm.

The full scale remediation of the Reedely site was conducted in June 1995 on 321 cubic yards of soil with concentrations of 400 mg/kg and greater. Total treatment time was less than 35 days. The California Department of Toxic Substance Control gave approval for the replacement of the treated soil and water back to the site in a unlined lagoon. This successful remediation will result in certification of the SABRE™ process for remediation of dinoseb in California.

CURRENT STATUS

The University of Idaho in cooperation with the Simplot Company have ongoing research programs to design improvements in this process and expand the applicability of this technology to specific sites and for additional chemical compounds. Additional work is being conducted to develop an in situ process for subsurface soil and groundwater. Simplot maintains an active research and development program at our facilities located in Pocatello, Idaho. An expanding staff of researchers conduct basic microbiological research, perform treatability studies, supervise field trials and oversee commercial applications of the technology.

Yorktown Naval Weapons Station: The Navy has selected the SABRE™ process to treat soils at site seven of Yorktown Naval Weapons Station, Virginia. Baker Environmental will perform field investigative and compliance work, and OHM will provide remediation services with the oversite from the J. R. Simplot Company. This full scale work will begin Summer of 1996.

Lake Ontario Ammunition Plant: The Baltimore Corps of Engineers has selected the SABRE™ process to remediate TNT explosive soils containing TNT nuggets at the Lake Ontario Ammunition Plant site. This work will begin Fall 1996.

Iowa Army Ammunitions Plant: Work plans have been prepared for agency approval on a full-scale remediation of 10,000 cubic yards of TNT-contaminated soil at Iowa Army Ammunitions Plant. The pilot scale phase is to begin the summer of 1996.

Ellensburg: The full-scale remediation of dinoseb using the SABRE™ process has been approved by state agencies for the Ellensburg, Washington site. The SABRE™ process has already been field proven highly effective remediating contaminates in soil at Ellensburg.

Because this is a proprietary technology and patented, all work with this technology has been and will be conducted with the approval and under the direction and supervision of the J.R. Simplot Company.

BENEFITS:

The following benefits have been observed and verified in laboratory studies and at field remediation sites when using the SABRE™ process:

Complete degradation of dinoseb and explosive compounds can be achieved without destroying soils. Remediated soils will be rich in organic carbon and minerals, with high nutritional value making them suitable for reuse.

TNT, HMX, RDX and their intermediates were reduced below regulatory limits. Actual degradation occurs, not just immobilization or transformation.

Nuggets of pure explosive material are also destroyed during treatment.

The toxic intermediates are destroyed without the formation of polymer materials which could be released into the environment.

The treated soil and water can be placed on site after treatment without future monitoring.

Treatment can be completed on site avoiding liability for shipping contaminated soils off site.

The SABRE™ process is a safe method of bioremediation because you are dealing with explosives in a water mixture.

The SABRE™ process has a high confidence factor of 99.4% , and has been independently field proven.

There are no particulate air emissions during the treatment phase of the SABRE™ process.

The SABRE™ process effectively degrades nitroaromatics at temperatures much lower than optimal for most bioremediation technologies. Degradation of dinoseb was demonstrated at 18°C.

This is a simple, flexible and natural process which easily finds public approval.

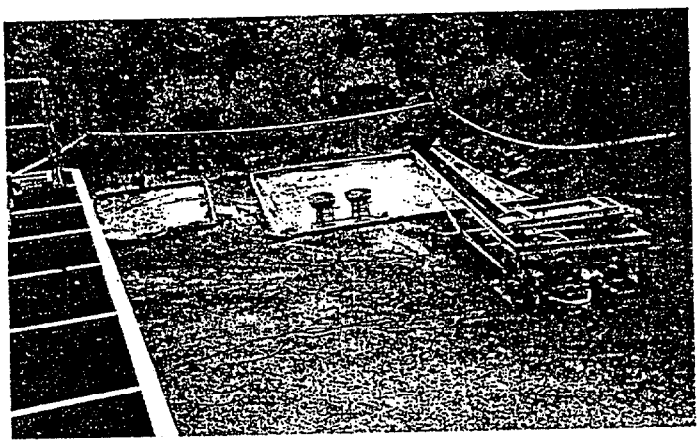
This bioremediation process is a cost effective alternative which can generate savings of 30% or more over other methods.

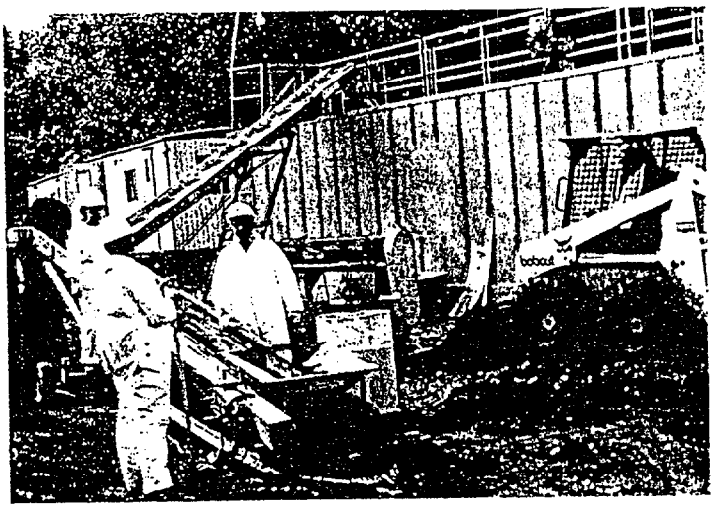
Environmental Protection Agency | Development | Washington DC 20460 | September 1995

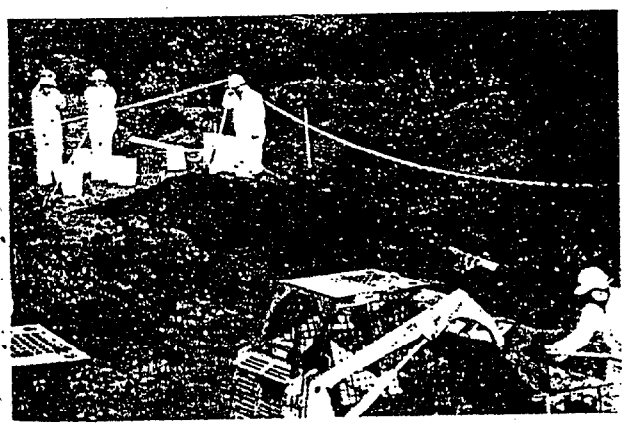
EPA

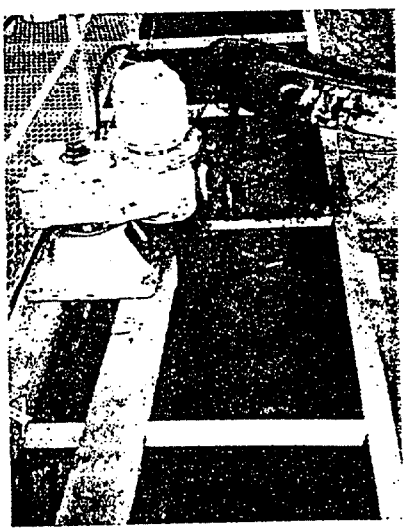
J.R. Simplot Ex-Situ Bioremediation Technology for Treatment of TNT-Contaminated Soils

Innovative Technology Evaluation Report









SITE

SUPERFUND INNOVATIVE TECHNOLOGY EVALUATION

EPA/540/R-95/529
September 1995

J.R. SIMPLOT
EX-SITU BIOREMEDIATION TECHNOLOGY FOR TREATMENT OF TNT-CONTAMINATED SOILS

INNOVATIVE TECHNOLOGY EVALUATION REPORT

NATIONAL RISK MANAGEMENT RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

NOTICE

The information in this document has been prepared for the U.S. Environmental Protection Agency's (EPA's) Superfund Innovative Technology Evaluation (SITE) Program under Contract No. 68-CO-0048. This document has been subjected to EPA's peer and administrative reviews and has been approved for publication as an EPA document. Mention of trade names of commercial products does not constitute an endorsement or recommendation for use.

FOREWORD

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory is the Agency's center for investigation of technological and management approaches for reducing risks from threats to human health and the environment. The focus of the Laboratory's research program is on methods for the prevention and control of pollution to air, land, water and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites and ground water; and prevention and control of indoor air pollution. The goal of this research effort is to catalyze development and implementation of innovative, cost-effective environmental technologies; develop scientific and engineering information needed by EPA to support regulatory and policy decisions; and provide technical support and information transfer to ensure effective implementation of environmental regulations and strategies.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

E. Timothy Oppelt, Director
National Risk Management Research Laboratory

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ACKNOWLEDGEMENTS

This report was prepared under the direction of Dr. Wendy Davis-Hoover, the EPA Technical Project Manager for this SITE Demonstration at the National Risk Management Research Laboratory (formerly the Risk Reduction Engineering Laboratory) in Cincinnati, Ohio. This report was prepared by the Process Technology Division of Science Applications International Corporation (SAIC). Contributors and reviewers for this report were Dr. Ron Lewis and Mr. Robert Stenberg of the EPA-NRMRL, Dr. Russ Kaake of the J.R. Simplot Company, and Mr. Craig Nowell formerly of Envirogen, Inc.

EXECUTIVE SUMMARY

This report summarizes the findings of the second evaluation of the J.R. Simplot Ex-situ Bioremediation Technology also known as the Simplot Anaerobic Bioremediation (SABRE™) process. This technology was developed by the J.R. Simplot Company to biologically degrade nitroaromatic and energetic compounds. The first evaluation was performed using soil contaminated with dinoseb, an agricultural herbicide. The second evaluation, and subject of this report, demonstrated the effectiveness of the process on the biodegradation of soil contaminated with 2,4,6-Trinitrotoluene (TNT). These evaluations were conducted under the U.S. Environmental Protection Agency (EPA) Superfund Innovative Technology Evaluation (SITE) Program.

Conclusions from this SITE Demonstration

Based on this SITE Demonstration, the following conclusions may be drawn concerning the applicability of the J.R. Simplot Ex-Situ Bioremediation Technology:

- The J.R. Simplot Bioremediation Technology can reduce the levels of TNT in the clayey gravel with sand soil by 99.4% based on an average pre-treatment slurry concentration of 1,500 mg/kg (on a dry basis) and a final average post-treatment slurry concentration of 8.7 mg/kg. This Reduction Efficiency has a 95% confidence interval of 98.3% to 99.9%. The treatment time associated with this Reduction Efficiency is approximately 9 months. QC data indicate that the post-treatment slurry concentration may be slightly biased thereby potentially lowering the overall Reduction Efficiency of the process. The Reduction Efficiency reported above is an overall "best" estimate based upon a statistically significant number of analytical results with no correction for spike recoveries.

- A 95% Reduction Efficiency, the critical objective of this demonstration, was achieved after approximately 5 months of remediation.

- Intermediate by-products resulting from the biological degradation of TNT were found to increase during the course of treatment and then decrease to below the analytical detection limit at the completion of the demonstration.

- Relative toxicity studies (early seedling growth, root elongation, and earthworm reproduction tests) from the commencement of the treatment process to a point approximately 5 months into the test showed that the technology had successfully reduced the toxicity of the contaminated soil.

- It is possible that remediation of the TNT contaminated soil is not uniform throughout the bioreactor. A large variability in the TNT concentrations existed in the post-treatment data. It is believed that one of the primary reasons for this variability in the post-treatment soil is because of an inability to completely wet the soil at the start of treatment due to the failure of the mixers while loading the soil and water into the bioreactor. The soil at this site consisted of a large clay content and therefore had a tendency to form soil clumps which were not easily broken apart prior to treatment. In addition, because of the rain that occurred on site once the soil was excavated soil clumps became more prevalent. While previous treatability tests (see below) have shown that mixing is not critical for the treatment to progress it is important that the soil is thoroughly wetted at the beginning of the treatment process. Because the soil was not easily broken apart during the pre-treatment processing phase and therefore the soil was not thoroughly wetted, it is possible that uniform treatment did not occur throughout the process. The consequence of this conclusion is that for similar soil types a comprehensive post-treatment sampling and analysis program may be required to determine if all TNT has been degraded.

- The negative process control showed that the degradation of TNT was a result of the J.R. Simplot Technology.

- The cost associated with this technology for treatment of 3,824 m^3 (5,000 yd^3) of TNT-contaminated soil in four lined pits is approximately \$147/m^3 (\$112/yd^3) for a treatment time of 6 months. This does not include costs for excavating the TNT-contaminated soil. Depending on site characteristics, an additional cost of up to \$131/m^3 (\$100/yd^3) may be assessed to the client by the developer for additional technical assistance, soil nutrients, a carbon source, and other process enhancements.

Conclusions that may be drawn regarding this technology, based on treatability studies and other pertinent information, include:

- The treatment time was found to be approximately 9 months, much longer than expected. This was due, in part, to the freezing conditions encountered which necessitated the inclusion of heaters to the system. Another time-limiting step was the diffusion of the TNT from the solid phase to the liquid phase within the bioreactor. The TNT degrading microorganisms thrive in the liquid phase of the bioreactor, therefore, the contaminants must be soluble, to some extent, in the liquid phase.

- Agitation of the bioreactor is required to ensure that diffusion of TNT into the liquid phase of the bioreactor. Although constant agitation of the bioreactor is not required, some form of "turning over" the soil in the bioreactor to create sufficient contact with the liquid phase is required.

- The presence of heavy metals in the soil does not adversely affect the process. As this technology is a sulfate reducing process, the toxic metals in the feed soil (e.g.: cadmium, lead, etc.,) are reduced to their sulfide forms thus, making the metals less toxic than in their original form *(1)*. Simplot claims that this technology is less susceptible to the effects of toxic metals than other bioremediation systems.

- If the feed soil contains greater than 1,000 mg/kg by weight total recoverable petroleum hydrocarbons (TRPH) then these hydrocarbons are thought to be toxic to the microorganisms *(1)*. However, if these hydrocarbons can be separated from the TNT-contaminated soil, the process is still applicable to the waste.

- The Simplot process can remediate most types of soil. However, pre-processing of the soil is required prior to placement into the bioreactor. This pre-processing may take longer for soils with a high clay content than for sandy type soils, thus increasing the cost of remediation. The low diffusivity of contaminants from clay soils to the water phase can also increase the treatment period. If the soil to be treated contains large rocks or debris, then this larger fraction must either be passed through a rock washing system with the washwater and fines being added to the bioreactor or crushed to the required size before being placed in the bioreactor.

The J.R. Simplot Ex-Situ Bioremediation Technology was evaluated based on the nine criteria used for decision-making in the Superfund Feasibility Study (FS) process. Table ES-1 presents this evaluation.

Table ES-1. Evaluation Criteria for the J.R. Simplot Ex-Situ Bioremediation Technology

Overall Protection of Human Health and the Environment	Compliance with Federal ARARs	Long-Term Effectiveness and Performance	Short-Term Effectiveness	Reduction of Toxicity, Mobility, or Volume through Treatment
Provides both short- and long-term protection by destroying contaminants in soil. Prevents groundwater contamination and off-site migration. Requires measures to protect workers and perhaps nearby communities during excavation, handling, and treatment.	Requires compliance with RCRA treatment, storage, and land disposal regulations (for a hazardous waste). Excavation, construction, and operation of on-site treatment unit may require compliance with location-specific ARARs. Emission controls may be needed to ensure compliance with air quality standards if volatile compounds are present. Wastewater discharges to POTW or surface bodies requires compliance with Clean Water Act regulations.	Permanently destroys contamination and intermediate compounds. Provides reduction in contamination levels; duration of treatment determines final contaminant levels. Overall toxicity reduced between pre- and post-treatment.	Presents potential short-term risks to workers and nearby community, including exposure to noise and contaminants released to air during excavation and handling. These can be minimized with correct handling procedures and borders.	Eliminates toxicity of soil contaminants through treatment. Does not leave intermediate compounds if conducted properly. Could result in intermediate compounds if terminated prematurely. If not fully dried, increases volume of treatment material by addition of water to create slurry.

Table ES-1. (Continued)

Implementability	Cost	Community Acceptance	State Acceptance
Major equipment is limited to bioreactor and agitation/suspension devices. Support equipment includes earthmoving equipment (for excavation, screening, and loading of bioreactor) and monitoring equipment (for tracking of pH, redox potential, and temperature). Once on-site, the small portable bioreactor can be assembled and ready to load within two days. The larger modular bioreactor requires approximately four days. After excavation, bioreactor loading activities (soil and water) are a function of the treatment volume. After treatment is complete, the small bioreactor can be emptied and demobilized in three days. If allowed by enforcement personnel treated soil can be placed in the excavated area and used as fill material. For erected bioreactors, the integrity of the liner can be intentionally breached when treatment is complete.	Estimated cost is $147/m^3 ($112/yd^3) for treatment in four lined pits, remediating a total of 3,824 m^3 (5,000 yd^3) of soil. Actual cost is site-specific and dependent upon: the volume of soil, soil characteristics, contaminants present, and original and target cleanup levels. Cost data presented in this table are for treating TNT-contaminated soil similar to the SITE Demonstration treatment soil. Costs presented are based on a 6 month batch treatment time, and exclude treatment soil excavation costs. Depending on site characteristics, an additional cost of up to $131/$m^3$ ($100/$yd^3$) may be assessed to the client by the developer for additional technical assistance, soil nutrients, a carbon source, and other process enhancements.	Minimal short-term risks presented to the community makes this technology favorable to the public. Public knowledge of common bioremediation applications (e.g., wastewater treatment) eases community acceptance for hazardous waste treatment using this technology. Use of naturally-selected microorganisms makes treatment by this technology a favorable option to the community. Low levels of noise exposure may impact community in the immediate vicinity.	If remediation is conducted as part of a RCRA corrective action, state regulatory agencies may require permits to be obtained before implementing the system. These may include a permit to operate the treatment system, an air emissions permit (if volatile compounds are present), a permit to store contaminated soil for more than 90 days, and a wastewater discharge permit.

SECTION 1
INTRODUCTION

This section provides background information about the Superfund Innovative Technology Evaluation (SITE) Program, discusses the purpose of this Innovative Technology Evaluation Report (ITER), and describes the J.R. Simplot Ex-Situ Bioremediation Technology. For additional information about the SITE Program, this technology, and the demonstration site, key contacts are listed at the end of this section.

1.1 Background

In 1987, the J.R. Simplot Company began working with researchers at the University of Idaho to develop a process to anaerobically degrade nitroaromatic compounds. In September 1990, the process was accepted into the SITE Emerging Technologies Program. A treatability study funded by the Emerging Technologies Program was performed by the University of Idaho on 9,000 kg (9.9 tons) of soil contaminated with the nitroaromatic herbicide, dinoseb. The results of this treatability study showed that the process could degrade dinoseb from approximately 20 mg/kg to below the analytical detection limit in 15 days. A transient unidentified intermediate compound was formed by the process, but the concentration of this intermediate compound was reduced to near the analytical detection limit within 45 days *(2)*. In April 1992, the J.R. Simplot Company applied, and was accepted into the SITE Demonstration Program. A full-scale demonstration of the technology was performed at an airport where the soil was contaminated with dinoseb. An evaluation of the J.R. Simplot Ex-Situ Bioremediation Technology using this listed RCRA waste as the contaminant of interest was performed in the summer of 1993. The results of this SITE Demonstration conducted at the afore-mentioned airport with supporting information from the bench-scale treatability studies conducted by the University of Idaho is described in a separate ITER. The results and conclusions of the SITE Demonstration with TNT as the contaminant of interest is the focus of this ITER.

The J.R. Simplot Ex-Situ Bioremediation Technology is a simple bioenhancement process that treats soils contaminated with nitroaromatic compounds by the addition of naturally selected anaerobic soil microorganisms. The process is initiated under aerobic conditions, but anaerobic conditions are quickly achieved under designed parameters, thus enabling the microbes to degrade the nitroaromatic

contaminants completely. As claimed by the developer, anaerobic degradation of nitroaromatics by the J.R. Simplot process takes place without the presence of any known toxic degradation products at the completion of treatment.

1.2 Brief Description of Program and Reports

The SITE Program is a formal program established by the EPA's Office of Solid Waste and Emergency Response (OSWER) and Office of Research and Development (ORD) in response to the Superfund Amendments and Reauthorization Act of 1986 (SARA). The SITE Program promotes the development, demonstration, and use of new or innovative technologies to clean up Superfund sites across the country.

The SITE Program's primary purpose is to maximize the use of alternatives in cleaning hazardous waste sites by encouraging the development and demonstration of new, innovative treatment and monitoring technologies. It consists of four major elements:

- the Demonstration Program,
- the Emerging Technology Program,
- the Measurement and Monitoring Technologies Program, and
- the Technology Transfer Program.

The objective of the Demonstration Program is to develop reliable performance and cost data on innovative technologies so that potential users may assess the technology's site-specific applicability. Technologies evaluated are either currently available or close to being available for remediation of Superfund sites. SITE Demonstrations are conducted on hazardous waste sites under conditions that closely simulate full-scale remediation conditions, thus assuring the usefulness and reliability of information collected. Data collected are used to assess: (1) the performance of the technology, (2) the potential need for pre- and post-treatment processing of wastes, (3) potential operating problems, and (4) the approximate costs. The demonstrations also allow for evaluation of long-term risks.

The Emerging Technology Program focuses on conceptually proven bench-scale technologies that are in an early stage of development involving pilot or laboratory testing. Successful technologies are encouraged to advance to the Demonstration Program.

Existing technologies that improve field monitoring and site characterization are identified in the Measurement and Monitoring Technologies Program. New technologies that provide faster, more cost-effective contamination and site assessment data are supported by this program. The Measurement and Monitoring Technologies Program also formulates the protocols and standard operating procedures for demonstration methods and equipment.

The Technology Transfer Program disseminates technical information on innovative technologies in the Demonstration, Emerging Technology, and Measurement and Monitoring Technologies Programs through various activities. These activities increase the awareness and promote the use of innovative technologies for assessment and remediation at Superfund sites. The goal of technology transfer activities is to develop interactive communication among individuals requiring up-to-date technical information.

1.3 The SITE Demonstration Program

Technologies are selected for the SITE Demonstration Program through annual requests for proposals. ORD staff reviews the proposals to determine which technologies show the most promise of use at Superfund sites. Technologies chosen must be at the pilot- or full-scale stage, must be innovative, and must have some advantage over existing technologies. Mobile technologies are of particular interest.

Once the EPA has accepted a proposal, cooperative agreements between the EPA and the developer establish responsibilities for conducting the demonstration and evaluating the technology. The developer is responsible for demonstrating the technology at the selected site and is expected to pay any costs for transport, operations, and removal of the equipment. The EPA is responsible for project planning, sampling and analysis, quality assurance and quality control, preparing reports, disseminating information, and transporting and disposing of treated waste materials.

The results of this evaluation of the J.R. Simplot Ex-Situ Bioremediation Technology for treatment of TNT-contaminated soil are presented in three documents: the SITE Technology Capsule, the Technical Evaluation Report (TER), and this Innovative Technology Evaluation Report. The SITE Technology Capsule provides relevant information on the technology, emphasizing key features of the results of the SITE field demonstration. The TER presents all data gathered during the SITE Demonstration and is a companion document to the ITER. The TER also presents all relevant QC information *(3)*. Both the

SITE Technology Capsule and the ITER are intended for use by remedial managers making a detailed evaluation of the technology for a specific site and waste.

1.4 Purpose of the Innovative Technology Evaluation Report (ITER)

This ITER is the second to be published regarding the J.R. Simplot Ex-Situ Bioremediation Technology. This ITER provides information on the treatment of TNT-contaminated soils using this approach and includes a comprehensive description of this demonstration and its results. The first ITER gives the results and conclusions regarding the efficacy of the technology for the treatment of the RCRA listed herbicide, dinoseb. The ITER is intended for use by EPA remedial project managers, EPA on-scene coordinators, contractors, and other decision-makers carrying out specific remedial actions. The ITER is designed to aid decision-makers in further evaluating specific technologies for further consideration as applicable options in a particular cleanup operation. This report represents a critical step in the development and commercialization of a treatment technology.

To encourage the general use of demonstrated technologies, the EPA provides information regarding the applicability of each technology to specific sites and wastes. The ITER includes information on cost and site-specific characteristics. It also discusses advantages, disadvantages, and limitations of the technology.

Each SITE Demonstration evaluates the performance of a technology in treating a specific waste. The waste characteristics of other sites may differ from the characteristics of the treated waste. Therefore, a successful field demonstration of a technology at one site does not necessarily ensure that it will be applicable at other sites. Data from the field demonstration may require extrapolation for estimating the operating ranges in which the technology will perform satisfactorily. Only limited conclusions can be drawn from a single field demonstration.

1.5 Technology Description

The J.R. Simplot Ex-Situ Bioremediation Technology is designed to destroy nitroaromatic and energetic compounds without the presence of any toxic intermediate compounds at the completion of remediation. The theory of operation behind the Simplot technology is that soils contaminated with these compounds may be treated using an anaerobic consortium. A consortium may be defined as a group of different

populations of microorganisms in close association that form a community structure with a certain symbiosis or interrelationship. Each population contributes to the general welfare of the group. An anaerobic consortium is a group of different populations of microorganisms that exist symbiotically without oxygen. Studies have found that anaerobiosis with redox potential less than -200 mV promotes the establishment of an anaerobic microbial consortium that degrades nitroaromatic compounds completely *(2)*. Under *aerobic* or microaerophilic conditions, degradation of nitroaromatic compounds may form degradation products that are potentially toxic. *Anaerobic* degradation of nitroaromatics using the J.R. Simplot technology takes place with the formation and then destruction of these degradation products.

Execution of the Simplot bioremediation technology is carried out by mixing a carbon source (a J.R. Simplot Company potato-processing starch by-product) with contaminated soil and then adding water and buffers to create a slurry. This prompts aerobic microorganisms to consume oxygen, thus creating anaerobic conditions in the treatment slurry. These conditions subsequently stimulate anaerobic microorganisms to consume toxins present in the slurry. The appropriate microorganisms are often indigenous to the treatment soil. Treatment soils may also be inoculated with the necessary consortium to initiate or enhance degradation rates. Treatment may take place in a small, mobile bioreactor or, when larger treatment soil volumes exist, in shallow, lined in-ground pits, or in large modular bioreactors.

Section 4.2 provides the specific details of the process design used during the Demonstration Test. Section 4.3 discusses the methodology behind the treatment and testing performed.

1.6 Key Contacts

Additional information on the J.R. Simplot Ex-Situ Bioremediation Technology and the SITE Program can be obtained from the following sources:

The J.R. Simplot Ex-Situ Bioremediation Technology

Russ Kaake, PhD
The J.R. Simplot Company
P.O. Box 912
Pocatello, ID 83201
Phone: (208) 234-5367
FAX: (208) 234-5339

The SITE Program

Robert A. Olexsey, Director
Superfund Technology Demonstration Division
U.S. Environmental Protection Agency
26 West Martin Luther King Drive
Cincinnati, Ohio 45268
Phone: (513) 565-7861
FAX: (513) 565-7620

Wendy Davis-Hoover, PhD
EPA SITE Technical Project Manager
U.S. Environmental Protection Agency
5995 Center Hill Avenue
Cincinnati, Ohio 45268
Phone: (513) 569-7206
FAX: (513) 569-7879

Information on the SITE Program is available through the following on-line information clearinghouses:

- The Alternative Treatment Technology Information Center (ATTIC) System [operator: (301) 670-6294] is a comprehensive, automated information retrieval system that integrates data on hazardous waste treatment technologies into a centralized, searchable source. This data base provides summarized information on innovative treatment technologies.

- The Vendor Information System for Innovative Treatment Technologies (VISITT) [hotline: (800) 245-4505)] data base currently contains information on approximately 231 technologies offered by 141 developers.

- The OSWER CLU-In electronic bulletin board contains information on the status of SITE technology demonstrations. The system operator can be reached at (301) 585-8368.

Technical reports may be obtained by contacting the Center for Environmental Research Information (CERI), 26 West Martin Luther King Drive in Cincinnati, Ohio, 45268 at (513) 569-7562.

SECTION 2
TECHNOLOGY APPLICATIONS ANALYSIS

This section of the report addresses the general applicability of the J.R. Simplot Ex-Situ Bioremediation Technology to contaminated waste sites. The analysis is based primarily on this SITE Demonstration, and conclusions are based exclusively on these data since only limited information is available on other applications of the technology. Supporting data from treatability studies performed by the University of Idaho are included. This SITE Demonstration was conducted on soil contaminated with TNT (2,4,6-trinitrotoluene).

2.1 Key Features of the J.R. Simplot Ex-Situ Bioremediation Technology

The J.R. Simplot Ex-Situ Bioremediation Technology has several unique features that distinguish it from most bioremediation technologies. Bioremediation using this technology is anaerobic. The anaerobic consortium used for degradation of nitroaromatic compounds is a consortium that has been naturally selected, and not genetically engineered. For the Demonstration Test, the necessary microorganisms were not indigenous to the local soil. Therefore, the test soil was inoculated with specific microorganisms to degrade the TNT.

Initially, consumption of oxygen by aerobic microorganisms is promoted by the addition of a carbon source. This carbon source is a J.R. Simplot Company potato-processing starch by-product. The potato starch mixture is made up of 42% solids; 215 mg of starch per gram; 6.7 mg of total nitrogen per gram; 2.6×10^4 culturable heterotrophic bacteria per gram; and 8×10^3 culturable amolytic bacteria per gram. The starch by-product is a stream that is normally discarded by the potato-processing industry (J.R. Simplot Co. uses it as a supplement to cattle feed), but in this case is beneficially utilized by the bioremediation system. In this manner, the process also acts as a reduction measure for the potato-processing industry.

The degradation of TNT using this bioremediation technology is not as temperature dependent as other biological systems. However, the degradation rate can be restricted if freezing conditions exist. This problem can be overcome by adding heaters to the system (as was the case during the Demonstration Test), but at an additional cost to the remediation.

This Demonstration Test has shown that treatment by the J.R. Simplot Ex-Situ Bioremediation Technology can attain a 99.4% Removal Efficiency of TNT. This Removal Efficiency was based upon the levels of TNT in the pre-and post-treatment slurries on a dry basis. Treatment by bioremediation may be more time-consuming than other treatment methods since the amount of contamination that is biologically degraded is a function of time. However, any technology that is technically and economically suitable for contaminated sites is of interest to remedial managers.

The J.R. Simplot Ex-Situ Bioremediation Technology is a cost-effective treatment method. The cost associated with this technology for biodegradation of TNT is approximately $147/m^3 ($112/yd^3) for 3,824 m^3 (5,000 yd^3) of soil treated in four lined pits. The J.R. Simplot Company may also impose a cost of up to $131/m^3 ($100/yd^3) to these estimated costs. This additional cost is dependent on site characteristics and is used for additional technical assistance, soil nutrients, and other process enhancements provided by the developer. The Economic Analysis associated with this technology is described in detail in Section 4 of this report.

2.2 Technology Performance versus ARARs during the Demonstration

Federal and state applicable or relevant and appropriate regulations (ARARs) for the J.R. Simplot Ex-Situ Bioremediation Technology are presented in Table 2-1. The performance of the technology during the Demonstration Test with respect to ARARs is discussed below.

Prior to treatment, the waste was characterized by performing chemical and physical analyses. The treatment soil was analyzed for TNT, pesticides, chlorinated herbicides, and metals. Tests were also performed to characterize the soil type; particle size distribution and Atterberg limits of the soil were determined. The waste was found to contain TNT and background levels of pesticides, herbicides, and toxic metals. The soil was classified as a clayey gravel with sand.

Because the pre-treatment waste carried hazardous characteristics as defined by RCRA, it was subject to RCRA regulations. (Only wastes that are defined as hazardous by bearing a RCRA characteristic or RCRA listing are subject to RCRA regulations.) After treatment, the waste no longer possessed any hazardous characteristics, so it was not handled as a hazardous waste.

Table 2-1. Federal and State ARARs for the J.R. Simplot Ex-Situ Bioremediation Technology

Process Activity	ARAR	Description	Basis	Response
Waste characterization (untreated waste)	RCRA 40 CFR Part 261 or state equivalent	Standards that apply to identification and characterization of waste to be treated	A requirement of RCRA prior to managing and handling the waste	Chemical and physical analyses must be performed.
	TSCA 40 CFR Part 761 or state equivalent	Standards that apply to the treatment and disposal of wastes containing PCBs	During waste characterization, PCBs may be identified in contaminated soil, and are therefore subject to TSCA regulations	Chemical and physical analyses must be performed. If PCBs are identified, soils will be managed according to TSCA regulations.
Soil excavation	Clean Air Act 40 CFR 50.6, and 40 CFR 52 Subpart K or state equivalent	Regulations governing the management of toxic pollutants and particulate matter in the air	Fugitive air emissions may occur during excavation and material handling and transport	If necessary, the waste material should be watered down or covered to eliminate or minimize dust generation.
	RCRA 40 CFR Part 262 or state equivalent	Standards that apply to generators of hazardous waste	Soils are excavated for treatment	If possible, soils should be fed directly into the bioreactor for treatment.
Storage prior to processing	RCRA 40 CFR Part 264 or state equivalent	Standards applicable to the storage of hazardous waste	Excavation and pre-treatment screening may generate hazardous wastes that must be stored in waste piles	If stored in a waste pile, the material should be placed on and covered with plastic, and tied down to minimize fugitive air emissions and volatilization. The time between excavation and treatment (or disposal if material is unsuitable for treatment) should be minimized.
Waste processing	RCRA 40 CFR Part 254 or state equivalent	Standards applicable to the treatment of hazardous waste at permitted and interim status facilities	Treatment of hazardous waste must be conducted in a manner that meets the operating and monitoring requirements; the treatment process may occur in a small, portable bioreactor or in a large, constructed bioreactor.	Equipment must be maintained daily. Integrity of bioreactor must be monitored and maintained to prevent leakage or failure. If treatment standards are not met, the bioreactor must be decontaminated when processing is complete.

Table 2-1. (Continued)

Process Activity	ARAR	Description	Basis	Response
Storage after processing	RCRA 40 CFR Part 264 or state equivalent	Standards that apply to the storage of hazardous waste	The treated material will remain in the bioreactor until it has been characterized and a decision on final disposition has been made. Oversize material unsuitable for processing may be stored in a waste pile.	Bioreactors must continue to be well-maintained. If stored in a waste pile, oversize material should be placed on and covered with plastic, and tied down to minimize fugitive emissions and volatilization. The material should be disposed of or otherwise treated as soon as possible.
Waste characterization (treated waste)	RCRA 40 CFR Part 261 or state equivalent	Standards that apply to waste characteristics	A requirement of RCRA prior to managing and handling the waste; it must be determined if treated material is RCRA hazardous waste.	Chemical and physical analyses must be performed on treated wastes and on oversize material prior to disposal.
	TSCA 40 CFR Part 761 or state equivalent	Standards that apply to the treatment and disposal of wastes containing PCBs	Treated wastes may still contain PCBs	Chemical and physical analyses must be performed on treated wastes and on oversize material prior to disposal. A proper disposal method must be selected if PCBs are found.
On-site/off-site disposal	RCRA 40 CFR Part 264 or state equivalent	Standards that apply to landfilling hazardous waste	Treated wastes and/or oversize material may still contain contaminants in levels above required cleanup action levels and therefore be subject to LDRs	Treated wastes and/or oversize material still defined as hazardous must be disposed of at a permitted hazardous waste facility, or approval must be obtained from the lead regulatory agency to dispose of the wastes on-site.
	TSCA 40 CFR Part 761 or state equivalent	Standards that restrict the placement of PCBs in or on the ground	Treated wastes and/or oversize material containing less than 500 ppm PCBs may be landfilled or incinerated	If untreated wastes contained PCBs, then treated wastes and oversize material should be analyzed for PCB concentration. Approved PCB landfills or incinerators must be used for disposal.

Table 2-1. (Continued)

Process Activity	ARAR	Description	Basis	Response
On-site/off-site disposal (continued)	RCRA 40 CFR Part 268 or state equivalent	Standards that restrict the placement of certain wastes in or on the ground	The nature of the waste may be subject to the LDRs	The waste must be characterized to determine if the LDRs apply. If so, waste must be handled in accordance with LDRs.
	SARA Section 121(d)(3)	Requirements for the off-site disposal of wastes from a Superfund site	The waste is being generated from a response action authorized under SARA	Wastes must be disposed of at a RCRA-permitted hazardous waste facility.
Transportation for off-site disposal	RCRA 40 CFR Part 262 or state equivalent	Manifest requirements and packaging and labelling requirements prior to transporting	The treated waste and/or oversize material may need to be manifested and managed as a hazardous waste	An identification (ID) number must be obtained from EPA.
	RCRA 40 CFR Part 263 or state equivalent	Transportation standards	Treated wastes and/or oversize material may need to be transported as hazardous wastes	A transporter licensed by EPA must be used to transport the hazardous waste according to EPA regulations.
Wastewater discharge	Clean Water Act 40 CFR Parts 301, 304, 306, 307, 308, 402, and 403	Standards that apply to discharge of wastewater into POTWs or surface water bodies	The wastewater may be a hazardous waste	Determine if wastewater could be directly discharged into a POTW or surface water body. If not, the wastewater may need to be further treated to meet discharge requirements by conventional processes. An NPDES permit may be required for discharge to surface waters

The waste did not contain PCBs, and therefore the ARARs pertaining to materials contaminated with PCBs were not applicable to this situation. It is unlikely that waste with PCB contamination would be treated by the J.R. Simplot Ex-Situ Bioremediation Technology because PCBs are not amenable to remediation by this technique.

During excavation, the wet nature of the waste material negated the need for dust suppression. No volatile contaminants were present in the treatment soil, therefore, volatile air emissions were not a concern during excavation. Although it was not possible to feed the soils directly into the bioreactor because of the logistical considerations associated with sampling during the Demonstration Test, the stockpiled excavated soil was kept covered with plastic and fed to the bioreactor as soon as it was sampled. During normal operation of the J.R. Simplot Ex-Situ Bioremediation Technology, it is anticipated that excavated soils may be screened, then homogenized with the carbon source and fed directly into the bioreactor. The J.R. Simplot Co. has stated that in future operations, the carbon source will be mixed with the water prior to the addition of the soil.

Before it was fed into the bioreactor, the Demonstration Test soil was screened to remove rocks and other debris greater than 15.9 mm (0.625 in) in diameter. Treatment of this oversize fraction may be performed by a soil or rock washing device at a later date. Alternatively, the oversize fraction may be crushed and fed into the bioreactor during subsequent treatment. It should be noted that, although soil or rock washing reduces the volume of contaminated material, waste requiring further treatment or disposal (e.g., contaminated wash water) will remain. In most cases, the waste resulting from soil or rock washing may be treated by the J.R. Simplot Ex-Situ Bioremediation Technology. If stored in a waste pile prior to treatment, the oversize material must be kept covered. If treated by a separate technology, the length of time that the oversize material is stored before treatment must be minimized.

Treatment of the Demonstration Test soil took place in a bioreactor that was maintained on a regular basis. The integrity of the bioreactor was monitored and maintained to prevent leakage or failure. Once treatment was complete, the post-treatment slurry was sampled and analyzed for TNT and known biodegradation by-products. The Missouri Department of Natural Resources (MDNR) specified a cleanup objective of 57 mg/kg for TNT and a total of 2.5 mg/kg for the sum of known byproducts of biological degradation for each sampling location. The results of the analyses of discrete samples indicated that

TNT in the post-treatment slurry was below the cleanup objective specified by the MDNR at all but one location within the bioreactor.

The treated material remained in the bioreactor until the results of post-treatment analyses were obtained and verified. The integrity of the bioreactor continued to be monitored and maintained. Based on analytical results, the treatment slurry was later pumped from the bioreactor into prepared lined pits for evaporation and filtering of the liquid phase without the need for decontamination. The liquid phase met the treatment standards set by the MDNR. In cases where the cleanup objective is not met, the bioreactor must be decontaminated when processing is complete and the slurry must be disposed of in an appropriate manner. Oversize material that was excavated during the Demonstration Test was stored in a waste pile on top of plastic liners. The pile was also covered with plastic and tied down. This material will be incinerated during full site remediation of the WSOW.

Using a conservative approach, personal protective equipment, debris contaminated during the Demonstration Test, and the spent on-site TNT test kits were handled as hazardous waste. All hazardous waste that was generated during the Demonstration Test was handled by WSOW personnel. The oversize fraction, if not treated on-site, must be transported off-site for treatment or disposal at a RCRA-permitted facility. Waste water generated by the remediation process was run through a sand filter and then passed through a carbon adsorber before discharged on-site. The carbon drum was handled as hazardous waste.

2.3 Operability of the Technology

The J.R. Simplot Ex-Situ Bioremediation Technology is a simple system. The system consists solely of the bioreactor equipped with agitation/suspension devices and monitoring equipment. Support equipment is only required to excavate, screen, and homogenize the soil and to load the bioreactor prior to treatment. During treatment, support equipment is not required. Small, portable bioreactors are mobile and operated by trained personnel. Large, excavated pits for use as bioreactors may be constructed with minimal effort as with modular tanks. The system may operate unattended for several days at a time, if necessary. The bioreactor appeared to be relatively free of operational problems during the demonstration in Weldon Spring, Missouri.

Several operating parameters influence the performance of the J.R. Simplot Ex-Situ Bioremediation Technology. These parameters are continually monitored. The technology is dependent on pH, redox potential, and temperature. The pH must be regulated by the addition of acids and/or phosphate buffers. Based on a limited parametric study, it appears that the preferred pH range for TNT degradation is between 6 and 7 *(2)*. Small variations in the pH of the slurry during the demonstration did not seem to adversely affect the behavior of the consortium. Anaerobic conditions suitable for the microorganisms that are capable of degrading TNT exist when the redox potential is less than -200 mV *(2)*. These anaerobic conditions are achieved when aerobic microorganisms consume oxygen from the soil and lower the redox potential. Although the treatment slurry should be mildly agitated to keep the solid fraction in suspension during treatment and to allow diffusion of the TNT from the solid phase to the liquid phase, rigorous mixing should not be performed to avoid aerating the slurry and recreating aerobic conditions. Treatability studies have shown that continuous mixing is not required *(4)*. A static system in sand type soils is known to achieve acceptable results when the soil, water, and carbon source are well-mixed during loading of the bioreactor. Temperature is a third parameter that may influence the performance of the J.R. Simplot Ex-Situ Bioremediation Technology. During the parametric study mentioned above, it was also found that a suitable operating temperature is between 35 and 37°C *(2)*.

During the demonstration, excavated soil was screened to separate rocks and debris greater than 15.9 mm (0.625 in) in diameter. The screening process was laborious, due in part to the inappropriately sized screening equipment and the wet nature of the clay type soil. Important knowledge and experience about full-scale operations were gained during the Demonstration Test.

To determine the amount of soil treated, the volume of the excavated soil may be measured geometrically, or the volume of soil fed into the bioreactor may be determined by counting the number of loads deposited onto the conveyor. Both techniques were employed during the SITE Demonstration. To determine the amount of water added, the volume of water in the bioreactor may be measured geometrically before the addition of any soil, or the volume of water fed into the bioreactor may be determined by using a totalizing flowmeter. Because a totalizing flowmeter was unavailable during the demonstration, a tank of known volume was used to transport water from the source to the test site. The water was then pumped from this tank into the bioreactor and the volume was recorded. The volume of water added to the bioreactor was verified using geometric calculations. This information is required to ensure that a correct ratio of soil to water is established and maintained in the treatment slurry. Accurate

measurements of these quantities were also required during the Demonstration Test to facilitate calculations for the TNT concentration in the treatment slurry.

2.4 Applicable Wastes

The J.R. Simplot Ex-Situ Bioremediation Technology is suitable for soils and liquids contaminated with nitroaromatic and energetic compounds. The medium to be treated must not contain high levels of toxic metals or any other compounds that may be detrimental to the appropriate microorganisms (e.g., hydrocarbons). Although high levels of hydrocarbons may inhibit the performance of the microorganisms, the hydrocarbons can be removed from the soil prior to bioremediation by using a cloud-point separation technique. This technique incorporates the addition of a surfactant/water solution to the waste. Heat aids the separation of the organic phase from the aqueous phase, and gravity aids the separation of the solid phase. The hydrocarbon waste stream generated by this technique must be treated using an alternate technology or disposed of at a permitted facility. The J.R. Simplot Ex-Situ Bioremediation Technology has been demonstrated on dinoseb (2-*sec*-butyl-4,6-dinitrophenol) in a separate SITE Demonstration.

Simplot claims that any soil type can be treated, provided that the soil is thoroughly mixed with the carbon source (J.R. Simplot Company potato-processing starch by-product). The soil itself need not contain the microorganisms necessary to degrade the contaminants since the bioreactor can be inoculated with the appropriate microorganisms. These microorganisms can be obtained from previous site remediations or treatability studies. If the soil to be treated contains large rocks or debris, then this larger fraction can be passed through a soil washing system to remove surface contamination and separate the fine material. The washwater and the fines may subsequently be treated in the bioreactor. Alternatively, the larger fraction may be crushed to an appropriate size and then fed into the bioreactor. During the Demonstration Test, the soil was screened at 15.9 mm (0.625 in) diameter. However, Simplot claims that rocks and debris up to 38.1 mm (1.5 in) diameter can be remediated. Soil washing of the oversize fraction was not attempted by Simplot during the Demonstration Test because of inadequate equipment. For future operations, it is anticipated that, if required, the oversized fraction will be cleaned by an independent rock or soil washing vendor using an already proven process.

2.5 Availability and Transportability of Equipment

Currently, the J.R. Simplot Company does not own any bioreactors, but rents and modifies mobile tanks to accommodate small-scale treatment. The small, portable tanks are wheel-mounted and can be transported by licensed haulers. For large-scale treatment where the treatment volume exceeds approximately 31 m^3 (40 yd^3), lined, excavated pits, or modular, fabricated tanks are likely to be used. Excavated pits can be constructed to accommodate any volume of treatment soil. The large modular tanks can be bolted together on-site and rented on a case-by-case basis. Each large tank can treat up to 956 m^3 (1,250 yd^3) of soil. If the treatment volume exceeds 956 m^3, multiple tanks can be used simultaneously. Agitation/suspension devices (mixers) and monitoring equipment can easily be transported by freight. Support equipment may be obtained locally and transported to the site by freight. Once all the equipment is on-site, the small portable system can be assembled in approximately two days. For the larger erect tanks or lined pits, the time required for loading of the system is a function of the soil volume.

Demobilization activities include emptying the bioreactor, decontaminating on-site equipment (if necessary), disconnecting utilities, disassembling equipment, and transporting equipment off-site. Demobilization requires approximately three days for the small portable bioreactor and approximately five weeks for the larger erected tanks.

2.6 Materials Handling Requirements

Before treatment can commence, the soil must be excavated, staged, screened, and loaded into the bioreactor. Soils should be kept moist if fugitive emissions or airborne particulates are expected. If present in the soil, most VOCs will volatilize into the atmosphere unless strict preventative measures are undertaken. These measures may include covering the excavated material and/or operating in an enclosed environment. At sites where VOCs are the primary contaminants, treatment by the J.R. Simplot Ex-Situ Bioremediation Technology is not recommended.

When the treatment soil contains large rocks or other debris, it must be passed through a vibrating screen (or other size-separating device) to remove the oversize material. This oversize material must be removed to facilitate adequate mixing of the treatment soil with the water to form a slurry. Large clumps

of soil which pass through the screen must also be broken apart to increase the surface area and thereby increase the number of sites available for attack by the microorganisms. The oversize fraction may be crushed or washed on-site using a separate rock or soil washing technology. The washwater generated by soil washing may be treated in the bioreactor. If not treated by an alternate technology on-site, the oversize material must be transported off-site for treatment or proper disposal at a permitted facility.

At some sites, water may be available from the facility or from a local water source. At remote locations, water may need to be transported to the site in water trucks. For treatment of 23 m^3 (30 yd^3) in a 75,700-L (20,000-gal) portable bioreactor, approximately 24,000 L (6,400 gal) of water are required. For large-scale treatment, the volume of water required will vary and is based on the amount of soil treated and the composition of the soil. In either case, approximately one liter (0.26 gal) of water is required for each kilogram (2.2 lb) of soil treated.

The J.R. Simplot Company potato-processing starch by-product that is mixed with the treatment soil as a carbon source for the microorganisms is generally transported to the site in 208-L (55-gal) drums or, alternatively, in a tanker truck. When stored for extended periods of time or when exposed to heat, the J.R. Simplot Company potato-processing starch by-product begins to naturally ferment, causing an increase in pressure inside the drums. When handling this material, particularly when opening the drums, strict precautions must be followed to avoid ruptures of the J.R. Simplot potato-processing starch by-product drums. Drum lids may be pierced to provide an escape route for gases that build up during fermentation. The size of the hole should be minimized to control the release of foul odors associated with fermentation.

The treated slurry is pumped from the bioreactor at the conclusion of treatment. Wastewater with few suspended solids may be discharged into a publicly owned treatment works (POTW) or a surface water body if treatment standards have been met. The remaining sludge can be pumped into lined pits for evaporation of the liquid phase with the dried product being disposed of in the appropriate manner.

2.7 Range of Suitable Site Characteristics

Locations suitable for on-site treatment using the J.R. Simplot Ex-Situ Bioremediation Technology must be able to accommodate lined pits or modular tanks (if used), utilities, support facilities, and support equipment. These requirements are discussed below.

Simplot proposes to excavate treatment pits for the remediation of contaminated soil. It is anticipated to place water to a depth of 0.61 m (2 ft.), add 0.61 m of contaminated soil to form the slurry, and leave 0.305 m (1 ft.) of freeboard at the surface to account for rainfall.

Utilities required for the Simplot bioremediation system are limited to water and electricity. Water is needed to create a treatment slurry in the bioreactor. As mentioned above, approximately one liter (0.26 gal) of water was required for each kilogram (2.2 lb) of soil added to the reactor during the Demonstration. Water is also required for cleanup and decontamination activities, if necessary. The J.R. Simplot Ex-Situ Bioremediation Technology requires an on-site electrical circuit to power the agitators, and screening and homogenization equipment. The electrical current needed is a function of the size of the equipment. Additional power is required for on-site office trailers, if present.

Support facilities include a contaminated soil staging area, a treated slurry storage area, a drum storage area, and an office area. The treated slurry that is generated must be stored in soil piles or in cleared areas and allowed to dry before it is suitable for ultimate disposal. Drums containing nutrients (J.R. Simplot Company potato-processing starch by-product) and waste personal protective equipment (PPE) must be stored in a drum storage area. In addition, a tank storage area to store water and wastewater may be required at some sites. These support facilities must be contained to control run-on and run-off. Mobile trailers may be used as office space on-site. These office trailers must be located outside the treatment area.

Support equipment for the J.R. Simplot bioremediation system includes earth-moving equipment, conveyor belts, a vibrating screen (or other size-separating device), and homogenization equipment (Hydrolance). Earth-moving equipment (including backhoes, front-end loaders, and bobcats) is needed to excavate and move soils. Earth-moving equipment is also needed to load soils onto the vibrating screen and the conveyor belts. Conveyor belts are required to move the screened soil into the

homogenization equipment and the bioreactor. The vibrating screen is used to remove large rocks and other debris, and the homogenization equipment is utilized to blend the soil and water together in the bioreactor to allow diffusion of the contaminant. A container for wastewater (if not discharged into the sewer) may also be necessary.

2.8 Limitations of the Technology

According to the developer, the scope of contaminants suitable for treatment using the J.R. Simplot Ex-Situ Bioremediation Technology is limited to nitroaromatic and other energetic compounds. This SITE Demonstration was conducted to evaluate the performance of the technology with respect to TNT only. The behavior of another nitroaromatic compound, dinoseb, was evaluated during an earlier demonstration. The results and conclusions regarding this demonstration are presented in a separate Innovative Technology Evaluation Report.

It has been established that high levels of hydrocarbons (approximately >1,000 ppm TRPH) may be toxic to the microorganisms necessary for biodegradation of nitroaromatic compounds. However, by using a cloud-point separation technique prior to bioremediation, hydrocarbons can be removed from the soil. The technology cannot reduce levels of inorganic compounds in contaminated soil. In fact, the presence of high levels of toxic metals may preclude the use of this technology.

Because the performance of the technology is temperature-sensitive, cold climates may adversely affect the rate of biodegradation. This was obvious during treatment in Weldon Spring, Missouri when temperatures were significantly below that considered optimal by the parametric study *(4)*. Heaters were added to the bioreactor (at an additional cost) to bring the temperature up to an acceptable level. Other tests have indicated that treatment can be performed with operating temperatures substantially below the optimum range of 35 to 37°C but the rate of degradation is slower, as expected. During the first SITE Demonstration on the biodegradation of dinoseb, the levels of dinoseb were reduced from 27.3 mg/kg to non-detect levels in 23 days with slurry temperatures that averaged 18°C.

For large-scale treatment, space requirements for the construction of lined pits may also restrict the use of this technology.

2.9 ARARS for the J.R. Simplot Ex-Situ Bioremediation Technology

This subsection discusses specific federal environmental regulations pertinent to the operation of the J.R. Simplot Ex-Situ Bioremediation Technology including the transport, treatment, storage, and disposal of wastes and treatment residuals. These regulations are reviewed with respect to the demonstration results. State and local regulatory requirements, which may be more stringent, must also be addressed by remedial managers. Applicable or relevant and appropriate requirements (ARARs) include the following: (1) the Comprehensive Environmental Response, Compensation, and Liability Act; (2) the Resource Conservation and Recovery Act; (3) the Clean Air Act; (4) the Safe Drinking Water Act; (5) the Toxic Substances Control Act; and (6) the Occupational Safety and Health Administration regulations. These six general ARARs are discussed below; specific ARARs that may be applicable to the J.R. Simplot Ex-Situ Bioremediation Technology are identified in Table 2-1.

2.9.1 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

The CERCLA of 1980 as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986 provides for federal funding to respond to releases or potential releases of any hazardous substance into the environment, as well as to releases of pollutants or contaminants that may present an imminent or significant danger to public health and welfare or to the environment.

As part of the requirements of CERCLA, the EPA has prepared the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) for hazardous substance response. The NCP is codified in Title 40 Code of Federal Regulations (CFR) Part 300, and delineates the methods and criteria used to determine the appropriate extent of removal and cleanup for hazardous waste contamination.

SARA states a strong statutory preference for innovative technologies that provide long-term protection and directs EPA to do the following:

- use remedial alternatives that permanently and significantly reduce the volume, toxicity, or mobility of hazardous substances, pollutants, or contaminants;
- select remedial actions that protect human health and the environment, are cost-effective, and involve permanent solutions and alternative treatment or resource recovery technologies to the maximum extent possible; and

- avoid off-site transport and disposal of untreated hazardous substances or contaminated materials when practicable treatment technologies exist [Section 121(b)].

In general, two types of responses are possible under CERCLA: removal and remedial action. The J.R. Simplot Ex-Situ Bioremediation Technology is likely to be part of a CERCLA remedial action. Between 1986 and 1992, ex-situ bioremediation technologies were selected with increasing frequency as source control remedies at 33 Superfund sites *(6)*.

Remedial actions are governed by the SARA amendments to CERCLA. As stated above, these amendments promote remedies that permanently reduce the volume, toxicity, and mobility of hazardous substances, pollutants, or contaminants. When using the J.R. Simplot Ex-Situ Bioremediation Technology, the total volume of material undergoing treatment is increased because water is added to the contaminated soil to provide a treatment slurry. Even so, the volume of identified contaminants in the soil is reduced by biological degradation of these compounds. Some biodegradation processes form toxic intermediate compounds which were not previously present in the contaminated media. The J.R. Simplot Ex-Situ Bioremediation Technology anaerobically degrades nitroaromatic contaminants without the presence of known toxic intermediate compounds at the completion of treatment, and thus reduces the volume, toxicity, and mobility of the contaminants.

On-site remedial actions must comply with federal and more stringent state ARARs. ARARs are determined on a site-by-site basis and may be waived under six conditions: (1) the action is an interim measure, and the ARAR will be met at completion; (2) compliance with the ARAR would pose a greater risk to health and the environment than noncompliance; (3) it is technically impracticable to meet the ARAR; (4) the standard of performance of an ARAR can be met by an equivalent method; (5) a state ARAR has not been consistently applied elsewhere; and (6) ARAR compliance would not provide a balance between the protection achieved at a particular site and demands on the Superfund for other sites. These waiver options apply only to Superfund actions taken on-site, and justification for the waiver must be clearly demonstrated.

2.9.2 Resource Conservation and Recovery Act (RCRA)

RCRA, an amendment to the Solid Waste Disposal Act (SWDA), is the primary federal legislation governing hazardous waste activities and was passed in 1976 to address the problem of how to safely dispose of the enormous volume of municipal and industrial solid waste generated annually. Subtitle C of RCRA contains requirements for generation, transport, treatment, storage, and disposal of hazardous waste, most of which are also applicable to CERCLA activities. The Hazardous and Solid Waste Amendments (HSWA) of 1984 greatly expanded the scope and requirements of RCRA.

RCRA regulations define hazardous wastes and regulate their transport, treatment, storage, and disposal. These regulations are only applicable to the J.R. Simplot Ex-Situ Bioremediation Technology if RCRA-defined hazardous wastes are present. If soils are determined to be hazardous according to RCRA (either because of a characteristic or a listing carried by the waste), all RCRA requirements regarding the management and disposal of hazardous waste must be addressed by the remedial managers. Criteria for identifying characteristic hazardous wastes are included in 40 CFR Part 261 Subpart C. Listed wastes from specific and nonspecific industrial sources, off-specification products, spill cleanups, and other industrial sources are itemized in 40 CFR Part 261 Subpart D. For the Demonstration Test, the technology was subject to RCRA regulations because TNT carries hazardous waste characteristics. RCRA regulations do not apply to sites where RCRA-defined hazardous wastes are not present.

For cases like the Demonstration Test at WSOW where the pre-treatment waste is defined as hazardous because it carries a RCRA characteristic (not a RCRA listing), it is anticipated that, once the contaminated material is treated by the J.R. Simplot Ex-Situ Bioremediation Technology, it will no longer be considered a hazardous waste. During the Demonstration Test, the J.R. Simplot Company met the cleanup objectives specified by MDNR except at one location within the bioreactor and altered the composition of the waste through treatment such that the treated waste did not possess any hazardous characteristics. Therefore, the treated material was not considered a hazardous waste.

Listed hazardous wastes (40 CFR Part 261 Subpart D) remain listed wastes regardless of the treatment they may undergo and regardless of the final contamination levels in the resulting effluent streams and residues. This implies that, even after remediation, treated wastes are still classified as hazardous if the pre-treatment material was a listed waste.

For generation of any hazardous waste, the site responsible party must obtain an EPA identification number. Other applicable RCRA requirements may include a Uniform Hazardous Waste Manifest (if the waste is transported), restrictions on placing the waste in land disposal units, time limits on accumulating waste, and permits for storing the waste.

Requirements for corrective action at RCRA-regulated facilities are provided in 40 CFR Part 264, Subpart F (promulgated) and Subpart S (partially promulgated). These subparts also generally apply to remediation at Superfund sites. Subparts F and S include requirements for initiating and conducting RCRA corrective action, remediating groundwater, and ensuring that corrective actions comply with other environmental regulations. Subpart S also details conditions under which particular RCRA requirements may be waived for temporary treatment units operating at corrective action sites and provides information regarding requirements for modifying permits to adequately describe the subject treatment unit.

2.9.3 Clean Air Act (CAA)

The CAA requires that treatment, storage, and disposal facilities comply with primary and secondary ambient air quality standards. During the excavation, transportation, and treatment of soils, fugitive emissions are possible. Fugitive emissions include (1) volatile organic compounds and (2) dust which may cause semivolatiles and other contaminants to become airborne. Soils must be watered down or covered with industrial strength plastic prior to treatment to prevent or minimize the impact from fugitive emissions. State air quality standards may require additional measures to prevent fugitive emissions. The J.R. Simplot Ex-Situ Bioremediation Technology is not designed to treat soils contaminated with volatile compounds. However, if volatile compounds are present, the system may be modified to include a cover, an exhaust fan, and carbon adsorbers or biofilters to treat volatile emissions generated by excavation of the soil.

2.9.4 Safe Drinking Water Act (SDWA)

The SDWA of 1974, as most recently amended by the Safe Drinking Water Amendments of 1986, requires the EPA to establish regulations to protect human health from contaminants in drinking water. The legislation authorized national drinking water standards and a joint federal-state system for ensuring compliance with these standards.

The National Primary Drinking Water Standards are found in 40 CFR Parts 141 through 149. Wastewater generated by the J.R. Simplot Ex-Situ Bioremediation Technology during the degradation of TNT is anticipated to be acceptable for discharge into a POTW. Analyses of the wastewater and approval by the local authorities will confirm this assumption.

2.9.5 Toxic Substances Control Act (TSCA)

The TSCA of 1976 grants the EPA authority to prohibit or control the manufacturing, importing, processing, use, and disposal of any chemical substance that presents an unreasonable risk of injury to human health or the environment. These regulations may be found in 40 CFR Part 761; Section 6(e) deals specifically with PCBs. Materials with less than 50 ppm PCB are classified as non-PCB; those containing between 50 and 500 ppm are classified as PCB-contaminated; and those with 500 ppm PCB or greater are classified as PCB. PCB-contaminated materials may be disposed of in TSCA-permitted landfills or destroyed by incineration at a TSCA-approved incinerator; PCBs must be incinerated. Sites where spills of PCB-contaminated material or PCBs have occurred after May 4, 1987 must be addressed under the PCB Spill Cleanup Policy in 40 CFR Part 761, Subpart G. The policy establishes cleanup protocols for addressing such releases based upon the volume and concentration of the spilled material. The J.R. Simplot Ex-Situ Bioremediation Technology is not suitable for PCB-contaminated wastes; alternative treatment must be undertaken to treat this type of contamination.

2.9.6 Occupational Safety and Health Administration (OSHA) Requirements

CERCLA remedial actions and RCRA corrective actions must be performed in accordance with the OSHA requirements detailed in 20 CFR Parts 1900 through 1926, especially Part 1910.120 which provides for the health and safety of workers at hazardous waste sites. On-site construction activities at Superfund or RCRA corrective action sites must be performed in accordance with Part 1926 of OSHA, which describes safety and health regulations for construction sites. State OSHA requirements, which may be significantly stricter than federal standards, must also be met.

All technicians operating the J.R. Simplot bioremediation system and all workers performing on-site construction are required to have completed an OSHA training course and must be familiar with all OSHA requirements relevant to hazardous waste sites. For most sites, minimum PPE for workers will

include gloves, hard hats, steel-toe boots, and Tyvek® suits. Depending on contaminant types and concentrations, additional PPE may be required. Noise levels are not expected to be high, with the possible exception of noise caused by pre-treatment excavation and soil handling activities. During this time, noise levels should be monitored to ensure that workers are not exposed to noise levels above a time-weighted average of 85 decibels over an eight-hour day. If noise levels increase above this limit, then workers will be required to wear ear protection. The levels of noise anticipated are not expected to adversely affect the community.

SECTION 3
ECONOMIC ANALYSIS

3.1 Introduction

The primary purpose of this economic analysis is to provide a cost estimate (not including profit) for commercial remediation of TNT-contaminated sites utilizing the J.R. Simplot Ex-Situ Bioremediation Technology. This analysis is based on the results of a SITE Demonstration Test that utilized a small-scale bioreactor with a soil batch capacity of 31 m^3, and also information provided by Simplot on future plans to remediate 3,824 m^3 (5,000 yd^3) sites. This economic analysis estimates expenditures for remediating a total volume of 3,824 m^3 of treatment soil in four lined pits utilizing the J.R. Simplot Ex-Situ Bioremediation Technology.

Remediation is anticipated to be performed in four lined pits. Each of the four lined pits are assumed to be 50 feet wide, 340 feet long, four feet deep, and have a one-foot berm. They are each capable of treating 956 m^3 (1,250 yd^3) of soil using the J.R. Simplot Bioremediation Technology. Thus, throughout this cost estimate they will be referred to as "956-m^3" lined pits. Each pit is double lined with 30-mil HDPE and has an 8-ounce geotextile underlayment beneath the liners. Approximately two inches of sand is placed between the two liners. A hydro-mixer is used to agitate the treatment slurry. This is a device that Simplot has developed to mix the soil with the water.

The actual Demonstration Test treated approximately 23 m^3 (30 yd^3) of soil with an average 2,4,6-trinitrotoluene (TNT) contamination level of 1,500 mg/kg (dry basis). The soil was classified as a clayey gravel with sand. During the Demonstration Test the critical objective of 95% TNT reduction was achieved within 156 days. Within 283 days a TNT reduction efficiency of 99.4% was achieved under far from optiminum conditions. For conditions considered to be more suitable for the bioremediation of TNT, with the same contamination levels as those encountered during the Demonstration Test, batch treatment times for this economic analysis are assumed to be six months. Treatment costs will be reduced for shorter treatment periods, and increase for longer treatment times. The total treatment period for treating 3,824 m^3 of soil in four lined pits is approximately seven months. This total treatment time includes: excavation of the pits, soil processing, and remediation. It does not include excavation of the treatment soil and demobilization.

3.2 Conclusions

Estimated costs for four 956-m^3 lined pits remediating a total volume of 3,824 m^3 of TNT-contaminated soil are approximately \$147/m^3 (\$112/yd^3). Table 3-1 breaks down these costs into categories and lists each category's cost as a percent of the total cost. Costs that are assumed to be the obligation of the responsible party or site owner have been omitted from this cost estimate and are indicated by a line (---) in Table 3-1. These total costs do not include additional charges that may be imposed by the J.R. Simplot Company. These additional costs may total up to \$131/m^3 (\$100/yd^3), depending on site-specific information.

Costs presented in this report are order-of-magnitude estimates as defined by the American Association of Cost Engineers, with an expected accuracy within +50% and -30%; however, because this is an innovative technology, the range may actually be wider.

3.3 Issues and Assumptions

The cost estimates presented in this analysis are representative of charges typically assessed to the client by the vendor, but do not include profit. As mentioned above, the total costs do not include an additional expense that may be charged by the J.R. Simplot Company. Depending on site characteristics, this additional expense may include supplementary technical assistance, soil nutrients and enhancements, and a carbon source. This could total up to \$131/m^3 (\$100/yd^3) to the cost of remediation.

Many actual or potential costs that exist were not included as part of this estimate. They were omitted because site-specific engineering designs that are beyond the scope of this SITE project would be required. Also, certain functions were assumed to be the obligation of the responsible party or site owner and were not included in the estimates.

Costs that were considered to be the responsible party's (or site owner's) obligation include: preliminary site preparation, excavation of the TNT-contaminated soil, permits and regulatory requirements, initiation of monitoring and sampling programs, effluent treatment and disposal, environmental monitoring, and site cleanup and restoration. These costs are site-specific. Thus, calculations are left to the reader so that relevant information may be obtained for specific cases. Whenever possible, applicable information

Table 3-1. Estimated Costs for Treatment Using The J.R. Simplot Ex-Situ Bioremediation Technology

Bioremediation Lined Pit Size Number of Lined Pits Total Treatment Volume Batch Treatment Time Approximated Total Project Period	986 m^3 (1,250 yd^3) 4 3,824 m^3 (5,000 yd^3) 6 Months 7 Months		
	$/m^3$	$/yd^3$	% of Total Cost
Site Facility Preparation Costs†	32.37	24.75	22.0%
Permitting & Regulatory Costs	---	---	---
Annualized Equipment Costs	33.15	25.35	22.6%
Startup & Fixed Costs	6.65	5.09	4.5%
Labor Costs	28.82	22.03	19.6%
Supplies Costs	0.24	0.18	0.2%
Consumables Costs	34.86	26.65	23.7%
Effluent Treatment & Disposal Costs	---	---	---
Residuals & Waste Shipping, Handling, & Transport Costs	0.18	0.14	0.1%
Analytical Costs	10.05	7.68	6.8%
Facility Modifications, Repair, & Replacement Costs	0.77	0.59	0.5%
Site Restoration Costs	---	---	---
Total Costs	$147/$m^3$	$112/$yd^3$	

† This does not include costs for excavation of the contaminated soil. It does include excavation cost for constructing the lined pits.

is provided on these topics so that the reader can independently perform the calculations required to acquire relevant economic data. Table 3-2 lists a summary of the expenditures included in the total estimated costs.

Other important assumptions regarding operating conditions and task responsibilities that could significantly impact the cost estimate results are presented below:

- Operating hours during treatment are assumed to be eight hours a day, five days a week for personnel. Site preparation operations are assumed to be 10 hours a day for seven days a week. Site preparation operations will take approximately four weeks.
- The soil being treated is similar to the TNT-contaminated soil treated during the Demonstration Test.
- A sufficient water supply of at least 200 gpm is available on-site. Costs will significantly increase if wells must be constructed and/or if water must be transported to the site.
- Operations take place in suitable weather conditions. If not, provisions for heating the bioreactor tanks will increase the treatment costs.
- The batch treatment time is six months. Costs will be directly effected if the treatment rate increases or decreases.
- Four lined pits are used to treat the TNT-contaminated soil. If Simplot scales their process up differently (such as using modular erected bioreactors, or different size and number of lined pits), then the treatment costs will vary.

3.4 Basis for Economic Analysis

The cost analysis was prepared by breaking down the overall cost into 12 categories:

- Site and facility preparation costs,
- Permitting and regulatory costs,
- Equipment costs,
- Startup and fixed costs,
- Labor costs,
- Supplies costs,
- Consumables costs,

Table 3-2. Items Included in This Cost Estimate

Cost Item	Included in Cost Estimate?
Site Design and Layout	NO
Survey and Site Investigations	NO
Preparation of Support Facilities	NO
Excavation of Contaminated Material	NO
Excavation of Lined Pits	YES
Construction of the Lined Pits	YES
Screening and Loading the Contaminated Soil into the Lined Pits	YES
Permitting and Regulatory	NO
Equipment Costs Incurred During Treatment	YES
Working Capital	YES
Insurance, Taxes, and Contingency	YES
Initiation of Monitoring Programs	NO
Labor Incurred During Treatment	YES
Labor Incurred During Demobilization and Site Restoration	NO
Travel	YES
Supplies	YES
Consumables (Fuel, Water, and pH Adjustment Chemicals)	YES
J.R. Simplot Potato-Processing By-Product (Starch)	NO
Effluent Treatment and Disposal	NO
Waste Shipping, Handling & Transportation for used PPE	YES
Environmental Monitoring Analytical	NO
Simplot Monitoring Analytical	YES
Design Adjustments, Facility Modifications, & Equipment Replacement	NO
Maintenance Materials	YES
Site Restoration & Demobilization (Including Drying the Slurry)	NO

- Effluent treatment and disposal costs,
- Residuals and waste shipping, handling, and transport costs,
- Analytical costs,
- Facility modification, repair, and replacement costs, and
- Site restoration costs.

These 12 cost categories reflect typical cleanup activities encountered on Superfund sites *(6)*. Each of these cleanup activities is defined and discussed, forming the basis for the detailed estimated costs presented in Table 3-3. The estimated costs are shown graphically in Figure 3-1. The 12 cost factors examined and assumptions made are described in detail below.

3.4.1 Site and Facility Preparation Costs

For the purposes of these cost calculations, "site" refers to the location of the contaminated soil. For these cost estimates, it is assumed that the space available at the site is sufficient for a configuration that would allow the J.R. Simplot Ex-Situ Bioremediation lined pits to be located near the contaminated soil. Thus, costs for transportation of the contaminated soil from the site to a separate facility where the Ex-Situ Bioremediation lined pits are located is not required for this cost estimate.

It is assumed that preliminary site preparation will be performed by the responsible party (or site owner). The amount of preliminary site preparation required will depend on the site. Site preparation responsibilities include site design and layout, surveys and site logistics, legal searches, access rights and roads, preparations for support and decontamination facilities, utility connections, excavation of the TNT-contaminated soil, and fixed auxiliary buildings. Since these costs are site-specific, they are not included as part of the site preparation costs in this cost estimate.

For the purposes of these cost calculations, installation costs are limited to shipping cost for the liners, and construction of the four lined pits. Shipping costs for all of the liners are estimated at a total cost of $2,400. Excavation costs for the lined pits is limited to rental equipment, fuel for the equipment, equipment operators, and labor to install the liners and geotextile underlayment for the liner. Excavation rental equipment includes: five 1-yd^3 excavators (each $2,100/wk), three 10-yd^3 box dump trucks (each $600/wk), and one backhoe ($700/wk) each rented for approximately three weeks. Fuel requirements

Table 3-3. Detailed Costs for Treatment Using the J.R Simplot Ex-Situ Bioremediation Technology (page 1 of 2)

Bioremediation Lined Pit Size	986 m^3 (1,250 yd^3)
Number of lined Pits	4
Total Treatment Volume	3,824 m^3 (5,000 yd^3)
Batch Treatment Time	6 Months
Approximated Total Project Period	7 Months

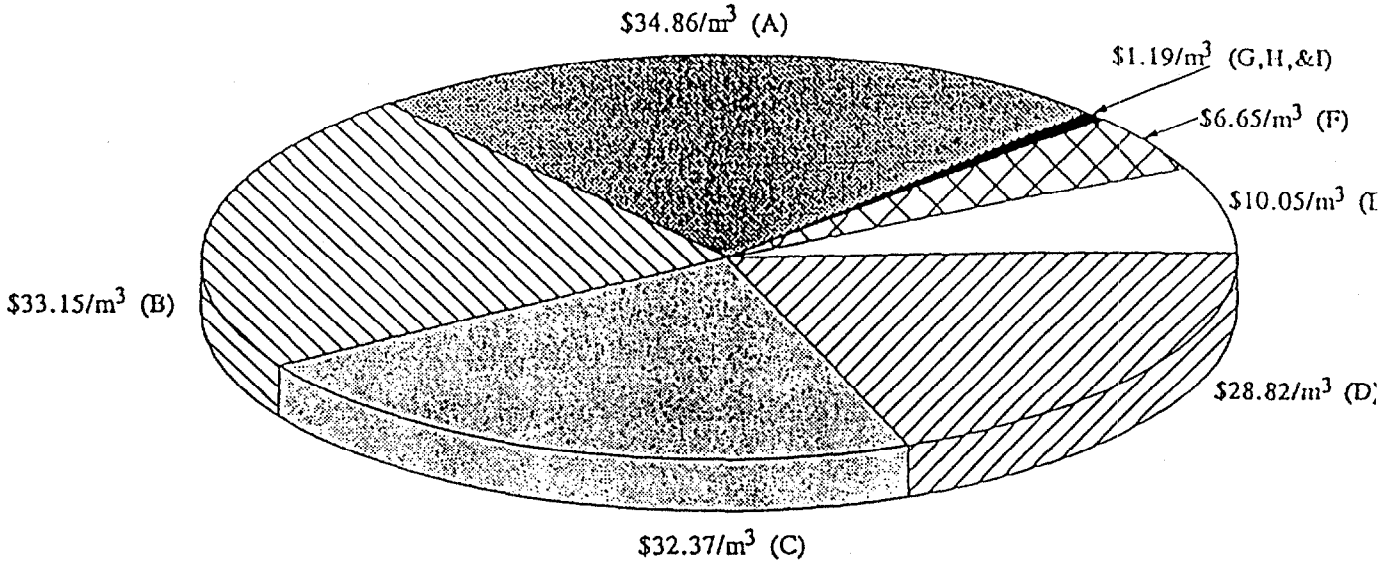
	$/m³	$/yd³
Site and Facility Preparation Costs		
Site design and layout	---	---
Survey and site investigations	---	---
Legal searches, access rights & roads	---	---
Preparations for support facilities	---	---
Auxiliary buildings	---	---
Excavation of the contaminated soil	---	---
Technology-specific requirements (construction of lined pits)	32.37	24.75
Transportation of waste feed	---	---
Total Site and Facility Preparation Costs	32.37	24.75
Permitting and Regulatory Costs		
Permits	---	---
System monitoring requirements	---	---
Development of monitoring and protocols	---	---
Total Permitting and Regulatory Costs	---	---
Equipment Costs		
Annualized equipment cost	1.80	1.38
Support equipment cost	24.88	19.02
Equipment rental	6.47	4.95
Total Equipment Costs	33.15	25.35
Startup and Fixed Costs		
Working capital	5.11	3.91
Insurance and taxes	0.77	0.59
Initiation of monitoring programs	---	---
Contingency	0.77	0.59
Total Startup and Fixed Costs	6.65	5.09
Labor Costs		
Supervisors	3.44	2.63
Health & Safety	0.71	0.54
Technicians	11.98	9.16
General	9.42	7.20
Secretary	1.96	1.50
Rental car	0.37	0.28
Travel	0.94	0.72
Total Labor Costs	28.82	22.03

(Continued)

Table 3-3. Detailed Costs for Treatment Using the J.R. Simplot Ex-Situ Bioremediation Technology (page 2 of 2)

Bioremediation Lined Pit Size	986 m^3 (1,250 yd^3)
Number of Lined Pits	4
Total Treatment Volume	3,824 m^3 (5,000 yd^3)
Batch Treatment Time	6 Months
Approximated Total Project Period	7 Months

	$/m³	$/yd³
Supplies Costs		
Personal protective equipment	0.24	0.18
Total Supplies Cost	0.24	0.18
Consumables Costs		
Fuel	0.78	0.60
Water	0.07	0.05
pH adjustment chemicals	34.01	26.00
Total Consumables Costs	34.86	26.65
Effluent Treatment and Disposal Costs		
On-site facility costs	---	---
Off-site facility costs	---	---
-wastewater disposal	---	---
-monitoring activities	0	0
Total Effluent Treatment and Disposal Costs	---	---
Residuals & Waste Shipping, Handling & Transport Costs		
Preparation	---	---
Waste disposal	0.18	0.14
Total Residuals & Waste Shipping, Handling & Transport Costs	0.18	0.14
Analytical Costs		
Operations	10.05	7.68
Environmental monitoring	---	---
Total Analytical Costs	10.05	7.68
Facility Modification, Repair, & Replacement Costs		
Design adjustments	0	0
Facility modifications	0	0
Maintenance materials	0.77	0.59
Equipment replacement	0	0
Total Facility Modification, Repair, & Replacement Costs	0.77	0.59
Site Restoration Costs		
Site cleanup and restoration	---	---
Permanent storage	---	---
Total Site Restoration Costs	---	---
TOTAL COSTS	**$147/m³**	**$112/yd³**



(A) Consumables Costs ($34.86/m^3)
(B) Annualized Equipment Costs ($33.15/m^3)
(C) Site Facility Preparation Costs ($32.37/m^3)
(D) Labor Costs ($28.82/m^3)
(E) Analytical Costs ($10.05/m^3)
* Permitting & Regulatory Costs

(F) Startup & Fixed Costs ($6.65/m^3)
(G) Facility Modifications, Repair, & Replacement Costs ($0.77/m^3)
(H) Supplies Costs ($0.24/m^3)
(I) Residuals & Waste Shipping, Handling, & Transport Costs ($0.18/m
* Effluent Treatment & Disposal Costs
* Site Restoration Costs

* - These costs are not included in this economic analysis.

Figure 3-1. Estimated Costs for the J.R. Simplot Ex-Situ Bioremediation Technology

are approximated at 3-gals/hr for each excavator, 2-gals/hr for each dump truck, and 3-gals/hr for the backhoe. Fuel cost are estimated a $1.00 per gallon. Equipment operators include five excavator operators (each $25/hr), three dump truck operators (each $25/hr), one backhoe operator ($25/hr), and one supervisor ($40/hr) for 10 hrs per day for approximately 17 days. Liner installation requires 12 general labors at $20/hour/person for 16 hours per lined pit and liner installation equipment (estimated at a total of $2,700).

Technology-specific site preparation requirements for the Ex-Situ Bioremediation Unit consist of soil screening, and soil and water loading into the bioreactor.

Equipment necessary for technology-specific site preparation for treatment includes: a vibrating screen, a conveyor belt, and a 50-kW diesel generator.

3.4.2 Permitting and Regulatory Costs

Permitting and regulatory costs are generally the obligation of the responsible party (or site owner), not that of the vendor. These costs may include actual permit costs, system monitoring requirements, and the development of monitoring and analytical protocols. Permitting and regulatory costs can vary greatly because they are site- and waste-specific. No permitting costs are included in this analysis; however depending on the treatment site, this may be a significant factor since permitting activities can be very expensive and time-consuming.

3.4.3 Equipment Costs

Equipment costs include purchased equipment, purchased support equipment, and rental equipment. Support equipment refers to pieces of purchased equipment and/or sub-contracted items that will only be used for this one remediation.

Purchased Equipment Costs

The purchased equipment costs are presented as annualized equipment costs, prorated based on the amount of time the equipment is used for the project. The annualized equipment cost is calculated using a 5-year equipment life and a 10% annual interest rate. The annualized equipment cost is based upon the writeoff of the total initial capital equipment cost and scrap value *(7,8)* (assumed to be 10% of the original equipment cost) using the following equation:

$$Capital\ recovery = (V - V_s)\ \frac{i(1 + i)^n}{(1 + i)^n - 1}$$

Where

V is the cost of the original equipment,

V_s is the salvage value of the equipment,

n is the equipment life (5 years), and

i is the annual interest rate (10%) *(7,8)*.

For this cost estimate, purchased equipment includes: four hydro-mixers (used for 7 months) at a total cost of $40,000, and four data loggers (used for 7 months) at a total cost of $10,000. The total cost of the purchased equipment is thus $50,000. This total cost is used to calculate the prorated annualized purchased equipment cost.

Support Equipment Costs

For estimating purposes, support equipment includes: double liners, geotextile underlayment for the liner, and 2 inches of sand between the liners for each pit ($22,700 per pit), a decontamination area ($300), four area lights ($245 each), and 12 probes to measure temperature, pH, and redox potential ($250 each). This support equipment will not be used on subsequent projects, and therefore these costs are not prorated.

Rental Equipment Costs

Rental equipment includes: a bobcat at $1,650/month for seven months, an office trailer at $330/month for seven months, a telephone at $30/month for seven months, portable toilet facilities at $30/month for seven months, and a 50-kW generator at $1,500/month for seven months.

3.4.4 Startup and Fixed Costs

For this cost estimate startup costs are limited to lined pit construction. Lined pit construction costs are included under "Site and Facility Preparation Costs." Working capital is based on the amount of money currently invested in supplies and consumables. The working capital cost of supplies and consumables is based on maintaining a one-month inventory of these items. (See "Supplies Costs" and "Consumables Costs" for the specific amount of supplies and consumables required for the operation of the system. These quantities were used to determine the amount of supplies and consumables required to maintain a one-month inventory of these items.)

Insurance and taxes are usually approximately 1% and 2 to 4% of the total purchased equipment capital costs, respectively. The cost of insurance for a hazardous waste process can be several times more. Insurance and taxes together are assumed for the purposes of this estimate to be 10% of the purchased equipment capital costs *(8)*.

The cost for the initiation of monitoring programs has not been included in this estimate. The monitoring program does not include sampling and analysis of the bioreactor contents to evaluate the bioremediation process. These costs are included under the "Analytical Costs" section. Depending on the site and the location of the system, local authorities may impose specific guidelines for monitoring programs. The stringency and frequency of monitoring (if required) may have significant impact on the project costs. Simplot does plan to monitor pH, redox potential, and temperature within the bioreactor using probes and data loggers. The cost of the data logger is included under purchased equipment, and the cost of the probes are included under support equipment in the "Equipment Costs" section.

A contingency cost of 10% of the equipment capital costs is allowed for any unforeseen or unpredictable cost conditions, such as strikes, storms, floods, and price variations *(8,9)*.

3.4.5 Labor Costs

Labor costs are limited to labor rates, per diem, daily transportation, and travel. Labor rates include overhead and administrative costs. Only supervisors, health and safety engineers, and technicians require per diem, daily transportation to the site, and round trip air travel to the site location. Support secretaries provide assistance from the home office and are not required to be present on-site. Loader operators and general operators are assumed to be local hires that will be trained and supervised by Simplot personnel. Thus, loader operators and general operators do not require per diem or daily transportation to the site. Per diem is estimated at $70/day/person. Daily transportation includes a rental car and fuel at $50/day. Round trip travel costs are assumed to be $600/round trip/person.

For this cost estimate, operating labor time on-site is assumed to be eight hours a day, five days a week. Labor requirements include: one supervisor at $70/hour for four weeks; one health and safety engineer at $55/hour for one week; two technicians at $45/hour/person for ten weeks; two general labors at $15/hour/person for 30 weeks; and one secretary at $25/hour for two hours a day, five days a week for

30 weeks. Travel includes six round trips (one trip for the supervisor, one trip for the health and safety engineer, and four trips total for the two technicians).

3.4.6 Supplies Costs

Supplies cost for this cost estimate is limited to personal protective equipment (PPE). The cost of PPE is estimated at $3 per set of PPE. It is assumed that approximately 300 sets of PPE will be required.

3.4.7 Consumables Costs

Consumables required for the operation of the J.R. Simplot Ex-Situ Bioremediation Technology are limited to buffer, fuel, electricity, and water. For the purposes of this economic analysis it is assumed that the cost of the buffer is $34/m^3 ($26/yd^3) of treatment soil. The fuel required for the Ex-Situ Bioremediation Unit is estimated at 380 L/week (100 gal/week) for 30 weeks. The water rate is assumed to be $0.05/1,000 L ($0.20/1,000 gal). Approximately 4,660,000 L (1,230,000 gals) of water are required for treatment of 3,824 m^3 of soil using the J.R. Simplot Ex-Situ Bioremediation Technology.

3.4.8 Effluent Treatment and Disposal Costs

One effluent stream is anticipated from the J.R. Simplot Ex-Situ Bioremediation Technology. This is the treated slurry from the Ex-Situ Bioremediation Unit. It is anticipated that the solid phase of the treated slurry can be dried and replaced within the excavated area or used as fill material. In states where cleanup levels have not been established or when cleanup levels are not met, then disposal of the soil at a RCRA-permitted facility may be necessary. The liquid phase of the slurry is anticipated to be non-hazardous and suitable for disposal to a local POTW. In cases where the proper permits have been acquired it may be possible that the integrity of the liner can be intentionally breached when treatment is complete, and the liner abandoned in place. For the purposes of this cost estimate, it was assume that this approach was taken.

3.4.9 Residuals and Waste Shipping, Handling and Transport Costs

Waste disposal costs including storage, transportation and treatment costs are assumed to be the obligation of the responsible party (or site owner). It is assumed that the only residuals or solid wastes generated from this process will be used PPE and decontamination water. The disposal cost for 208-L (55-gal) drums of used PPE and/or decontamination water is estimated at $225/208-L drum. For this cost estimate, it is assumed that three 208-L drums of used PPE and decontamination water will be generated.

3.4.10 Analytical Costs

Only spot checks executed at Simplot's discretion (to verify correct performance of the equipment and that cleanup criteria are being met) are included in this cost estimate. The client may elect, or may be required by local authorities, to initiate a planned sampling and analytical program at their own expense. The cost for Simplot's spot checks is estimated at $200 per sample. For the purposes of this cost estimate, it is assumed that there will be approximately 190 samples analyzed.

The analytical costs associated with environmental monitoring (not process monitoring) have not been included in this estimate due to the fact that monitoring programs are not typically initiated by Simplot. Local authorities may impose specific sampling criteria whose analytical requirements could contribute to the cost of the project.

3.4.11 Facility Modification, Repair and Replacement Costs

Maintenance costs are assumed to consist of maintenance labor and maintenance materials. Maintenance labor and materials costs vary with the nature of the waste and the performance of the equipment. For estimating purposes, the annual maintenance labor and materials cost is assumed to be 10% of the purchased equipment capital costs. Costs for design adjustments, facility modifications, and equipment replacements are not included in this cost estimate.

3.4.12 Site Restoration Costs

Site restoration requirements will vary depending on the future use of the site and are assumed to be the obligation of the responsible party. Therefore, no site cleanup and restoration costs are included in this cost estimate.

SECTION 4
TREATMENT EFFECTIVENESS DURING THE SITE DEMONSTRATION

This section presents the results of the SITE Demonstration in Weldon Spring, Missouri and discusses the effectiveness of treatment at the Weldon Spring Ordnance Works (WSOW) by the J.R. Simplot Ex-Situ Bioremediation Technology.

4.1 Background

The Weldon Spring Ordnance Works (WSOW) is a former army ordnance factory located in rural Weldon Spring, Missouri. State regulatory agencies have detected 2,4,6-trinitrotoluene (TNT) contamination at this site. TNT is a nitroaromatic compound used in the production of munitions. The U.S. Corps of Engineers allowed the J.R. Simplot Company to evaluate their technology for the remediation of TNT-contaminated soils at this facility. The evaluation was initiated in cooperation with the EPA under the SITE Demonstration Program. A partial site characterization was performed in April 1993 by Science Applications International Corporation (SAIC), a contractor to the EPA. The investigation was not intended to fully characterize the site, but to identify the location and level of TNT-contaminated soil for use in the SITE Demonstration Test. The results of the site characterization indicated that the levels of TNT were appropriate and of enough volume to be suitable for the technology evaluation. Neither volatile or semivolatile organic compounds were detected by SW-846 Methods 8240 and 8270. Other pesticides, herbicides, and metals were identified in low concentrations as being present in the soil. However, TNT was the only target analyte selected for the Demonstration Test.

The only critical objective for the Demonstration Test was based on the developer's claim—that TNT contamination in soil could be reduced by at least 95% using their technology. This critical objective was determined based on the TNT concentration in the pre-treatment slurry (dry basis) and the post-treatment slurry (dry basis). Results were to be reported as percent reduction in the slurry (dry basis).

Non-critical objectives for the Demonstration Test were:

- to determine if the reduction of TNT contamination was a result of the J.R. Simplot Ex-Situ Bioremediation Technology;

- to determine if the reduction of TNT contamination was a result of biodegradation;
- to determine the relative toxicity of the test soil before and after treatment;
- to determine the presence of process intermediate compounds, RDX, and HMX in the soil before and after treatment;
- to determine if pesticides and herbicides were present in the test soil and, if so, to establish their levels of contamination;
- to determine the metals contamination in the soil before treatment;
- to determine the type of soil being remediated; and
- to develop operating costs.

The use and manipulation of microorganisms for treatment of waste, particularly wastewater, has been applied for many years. Bioremediation, or enhanced microbial treatment, now has many other applications including soils, sludges, groundwater, process water, and surface waters. Treatment may take place under aerobic or anaerobic conditions. Although bioremediation has met much success, degradation products that are potentially toxic are often formed under aerobic or microaerophilic conditions. The J.R. Simplot Company has developed a simple bioenrichment procedure that achieves anaerobic conditions under which a microbial consortium can degrade nitroaromatic compounds in soil and destroy any known toxic degradation products that are formed by the process.

4.2 Detailed Process Description

The J.R. Simplot Ex-Situ Bioremediation Technology takes place in a bioreactor. Portable tanks with a volume of 75,700-L (20,000-gal) are used to treat up to 31-m^3 (40-yd^3) of soil. For larger soil volumes, lined, in-ground pits can be constructed to act as bioreactors, or alternatively, erected modular tanks with a volume of 2.84 million-L (750,000-gal) are used to treat up to 956-m^3 (1,250 yd^3) of soil. When the treatment volume exceeds 956 m^3, multiple modular bioreactors may be used simultaneously.

Simplot utilized a portable tank as the bioreactor during the Demonstration Test because the volume of test soil was small—only 23 m^3 (30 yd^3). The bioreactor for these tests was 12.2 m long, 2.4 m wide, and 2.6 m tall (40 ft × 8.0 ft × 8.5 ft). To facilitate mixing, water was placed in the bioreactor with the soil in a ratio of approximately 1 L (0.26 gal) water to 1 kg (2.2 lb) soil. Nutrients (J.R. Simplot

Company potato-processing starch by-product) and pH-regulating agents were added to induce the aerobic microorganisms to consume oxygen from the soil. This lowered the redox potential (E_h) and created anaerobic conditions. Tests have shown that anaerobic conditions with E_h less than -200 mV promote the establishment of the anaerobic microorganisms capable of degrading TNT and other nitroaromatic compounds *(2)*.

Figure 4-1 shows the flow diagram for the Simplot process as operated during the Demonstration Test. Initially, the excavated test soil was sent through a vibrating screen to remove large rocks and other debris greater than 15.9 mm (0.625 in) in diameter. This larger fraction was not remediated during the Demonstration Test. Simplot claims that this oversize can be reduced in size to the required diameter by crushing equipment or that the contamination on the rocks and debris can be removed by a soil washing system with the wash water being placed in the bioreactor for treatment. After the soil, water, and nutrients were loaded in the bioreactor, the mixture was inoculated with 0.02 m^3 (a 5-gallon pail) of soil previously treated by the Simplot process during treatability studies for this site. This previously-treated soil contained the naturally selected microorganisms necessary for the degradation of TNT using the J.R. Simplot Ex-Situ Bioremediation Technology.

The bioreactor was loosely covered and equipped with two mixers for agitation. The mixers were installed to achieve a well-mixed slurry in the bioreactor. However, during loading of the bioreactor the motors on these mixers failed. Therefore, "dead spots" (i.e. settled sediment that did not receive agitation) occurred in the bioreactor due to insufficient mixing of the slurry by the agitators. Although previous testing indicated that the effect of the dead spots on the J.R. Simplot Ex-Situ Bioremediation Technology is not significant, the bioreactor was lanced to agitate these dead spots. This was accomplished by placing the suction end of a diaphragm pump into the settled sediment and pumping the sediment into a more well-mixed region of the bioreactor. The bioreactor was also equipped with instrumentation to monitor pH, temperature, and redox potential. A limited study has shown that suitable operating conditions are: temperature between 35 and 37°C, pH below 8.0 (ideally between 7.5 and 8.0 for TNT degradation), and redox potential $<$-200 mV *(2)*.

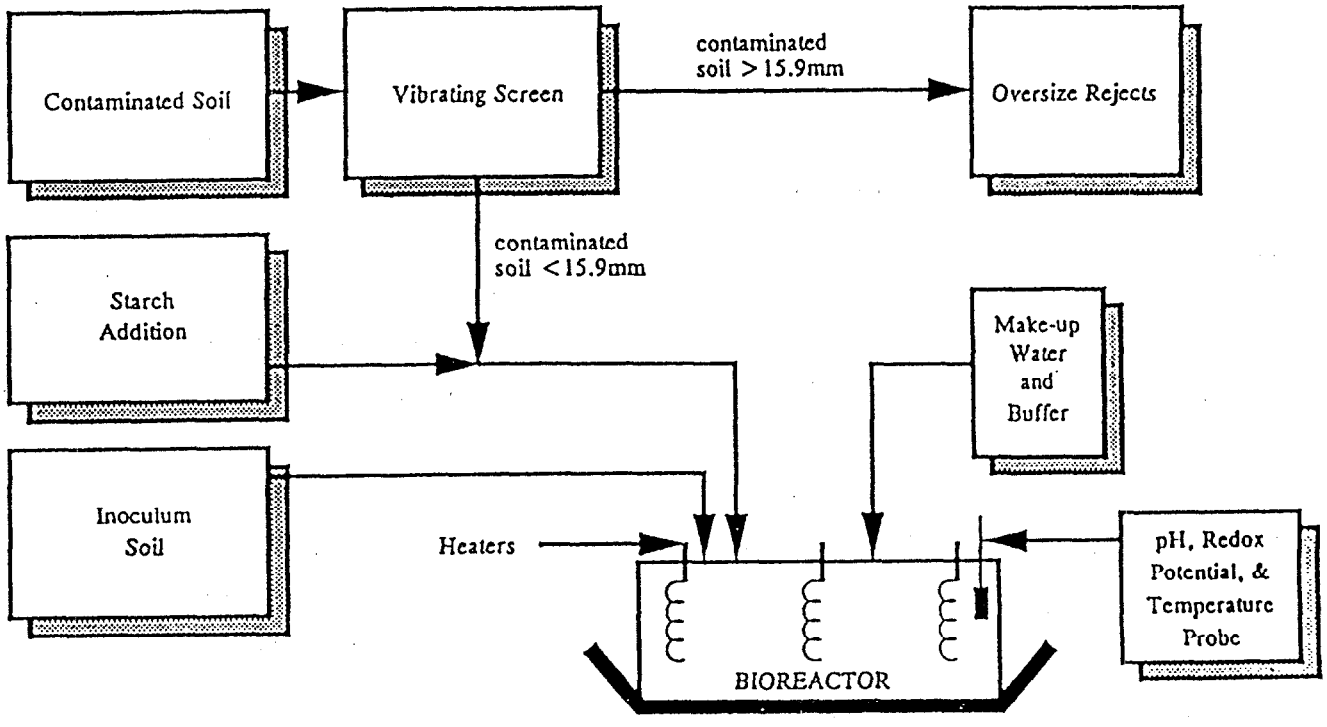


Figure 4-1. J.R. Simplot Process Flow Diagram for the Bioremediation of TNT-Contaminated Soil During the Demonstration Test

4.3 Methodology

Prior to commencement of the Demonstration Test, it was decided that evaluation of the J.R. Simplot Ex-Situ Bioremediation Technology would begin after the excavated soil was screened. Therefore, sampling of the pre-treatment feed soil for all parameters occurred after the soil had been excavated and passed through the screening process. For informational purposes, three composite samples of the pre-screened material were collected for particle size and Atterberg limits determination to evaluate the type of soil that could be processed by the overall system (including screening).

Excavation of the test soil was performed by the J.R. Simplot Company, assisted by Envirogen, Inc. Simplot and Envirogen determined the location of the soil to be excavated based on the limited site characterization previously performed by SAIC. Excavated soil was passed through a vibrating screen to separate out rocks and other debris greater than 15.9 mm (0.625 in) in diameter. Each fraction (the screened test soil and the oversize material) was placed in a separate lined area and covered for storage before sampling and processing. The screening process took longer than anticipated because of the wet nature of the clay type soil. The screened soil pile was leveled and shaped into a flat, truncated pyramid-like form. All sides of the pile were measured so that the approximate total soil volume could be geometrically determined. The soil volume was also determined as a cross check by determining the number of front-end loader batches that were placed onto the conveyor. The volume of the front-end loader was measured prior to soil loading. Three composite samples were collected from this pile for particle size and Atterberg limits determination. All materials > 15.9 mm in diameter were not evaluated as part of this demonstration.

The screened soil was collected in a small front-end loader to facilitate loading of the soil into a hopper before hand mixing with the carbon source. The carbon source consisted of a J.R. Simplot Company potato-processing starch by-product that was added to the soil. This starch was comprised of the materials stated in Section 2.1. Soil samples were collected from each front-end loader batch before the starch by-product was added. Simplot claims that in the future the starch will be mixed directly into the water before the soil addition.

In order to measure the variability of TNT contamination in the treatment soil, a grab sample was collected from every front-end loader batch fed into the hopper as mentioned above. After four grab

samples, the soil was homogenized and appropriate aliquots were collected. A total of 41 primary samples were collected for TNT analysis. Four field duplicates were collected for TNT analysis to measure sampling and compositing variability. Four samples were taken to determine if any known biological degradation products of TNT could be found. Samples of soil that were known to be free of TNT contamination were taken so that TNT spiking could be performed to determine if any matrix interferences were present in the treatment soil. Samples of this soil were also taken for use as the reference samples in the toxicity test (see below).

A soil density grab sample was collected in metal sleeves of known mass and volume from every sixth front-end loader batch. A total of 27 soil density grab samples were collected. The volume of each metal sleeve was determined on-site using a calibrated Vernier caliper. The mass of each metal sleeve was also determined on-site using a certified calibrated balance. The soil density and total soil volume were used to determine the mass of treatment soil.

Thirteen composite samples each were collected for pesticides, chlorinated herbicides, and metals analysis. These samples were collected in a manner similar to the TNT samples; a grab sample was collected from every front-end loader batch. After every twelve grab samples, the soil was homogenized and appropriate aliquots were collected. One field duplicate each was collected for pesticides, chlorinated herbicides, and metals.. MS/MSD analyses were performed on aliquots of one pesticide and one chlorinated herbicide sample. MS and analytical duplicate (AD) analyses were performed on aliquots of one metals sample.

A negative process control was set up prior to the start of the Demonstration Test as a means of comparing naturally occurring TNT degradation to degradation by the Simplot process. Grab samples were collected from each front-end loader batch to comprise a composite sample of the entire feed stream for the negative process control. The sample was homogenized and placed in a covered 19-L (5-gal) container near the bioreactor. This sample then remained in place during the entire demonstration period.

Grab samples were collected from each front-end loader batch to comprise composite samples of the entire feed stream for toxicity tests. These toxicity tests included earthworm reproduction, early seedling growth, and root elongation. Reference samples for the toxicity tests were also collected to compare to

the toxicity of uncontaminated soil with TNT-contaminated soil. Except for having no TNT contamination, this soil had the same characteristics and composition as the treatment soil.

Based on the amount of soil to be treated, a total of 24,000 L (6,400 gal) of make-up water was added to the bioreactor. This water was sampled before introducing the soil into the bioreactor. Three samples were analyzed each for TNT, pesticides, chlorinated herbicides, and metals.

After the soil, water, and nutrients were added, a sterile process control was set up at the start of the Demonstration Test by collecting slurry directly from the bioreactor (day 0). This sample was to be sterilized, using gamma radiation, to destroy any existing microorganisms and then returned to the vicinity of the bioreactor. Degradation of TNT in the bioreactor and lack of degradation in the sterile control under similar conditions would indicate that TNT degradation in the bioreactor was biological. The sterile process control was not evaluated since the level of gamma radiation did not fully sterilize the control based upon biological counts of the slurry.

Monitored parameters during remediation were pH, temperature, and redox potential. Measurements of these parameters were taken every 15 seconds and recorded on a data logger. However, at the completion of remediation, while down loading the data from the data logger considerable periods of data were lost.

During the course of remediation, conditions more than sufficient for anaerobic TNT degradation (E_h < -200 mV) were achieved in 26 days. The biodegradation of TNT by this process requires that the microorganisms break the NO linkage forming amino groups. This causes the slurry to become more alkaline, therefore, requiring the addition of hydrochloric acid to maintain the pH. Due to the unusually cold winter experienced during 1994, the temperature in the bioreactor often neared the freezing mark. This was lower than the preferred bioreactor temperature of 35 to 37°C *(2)*. To overcome this, 3 immersion heaters were added to the bioreactor to avoid freezing conditions.

In order to determine the amount of TNT reduction, daily samples of the treatment slurry were taken at five locations throughout the bioreactor and tested in the field using a simple TNT test method with selected samples being shipped to the laboratory for an abbreviated Method 8330 analysis *(10)*. Complete sampling and analysis of the contents of the bioreactor were obtained after approximately 5 months of

treatment (day 156). Analysis of these samples indicated that the TNT had not been completely degraded in all of the samples. Final post-treatment sampling was initiated 9 months (day 283) after the commencement of the tests.

At the mid-point sampling stage (5 months after test initiation-day 156) 50 primary samples were taken from the bioreactor to determine the level at which the TNT had been remediated. These samples were collected using a stratified approach to determine the required number of samples from the top, middle, and bottom layers of the bioreactor. Sample stratification and slurry concentration calculations were based on the total mass of soil in each layer. Once the number of samples to be collected from each layer was determined, the sample locations within each layer were chosen randomly. Five samples were taken to determine the level of intermediate compounds throughout the reactor. Three samples were also collected from the bioreactor for lead analysis. Slurry samples were obtained for the post-treatment toxicity tests.

All post-treatment slurry samples (day 283) were obtained using the same stratified approach used during the mid-point sampling (day 156) within the bioreactor. A total of 40 post-treatment slurry samples were collected and analyzed for TNT. Four field duplicate samples were collected for TNT to measure sampling variability and MS/MSD analysis was performed on aliquots of four TNT samples.

4.4 Performance Data

This section presents the performance data gathered for this demonstration by the testing methodology described above. Results are presented and interpreted below.

4.4.1 Chemical Analyses

TNT: A total of 41 pre-treatment (day 0), 50 mid-point (day 156), and 40 post-treatment (day 283) were analyzed by the Lockheed Analytical Laboratory for TNT using modified SW-846 8330 *(10)*. Sampling occurred on a daily basis at five locations within the bioreactor, as shown in Figure 4-2. These samples were analyzed using a field test kit to give approximate levels of TNT within certain areas of the bioreactor. A number of these samples were also analyzed at the laboratory using a shortened run time

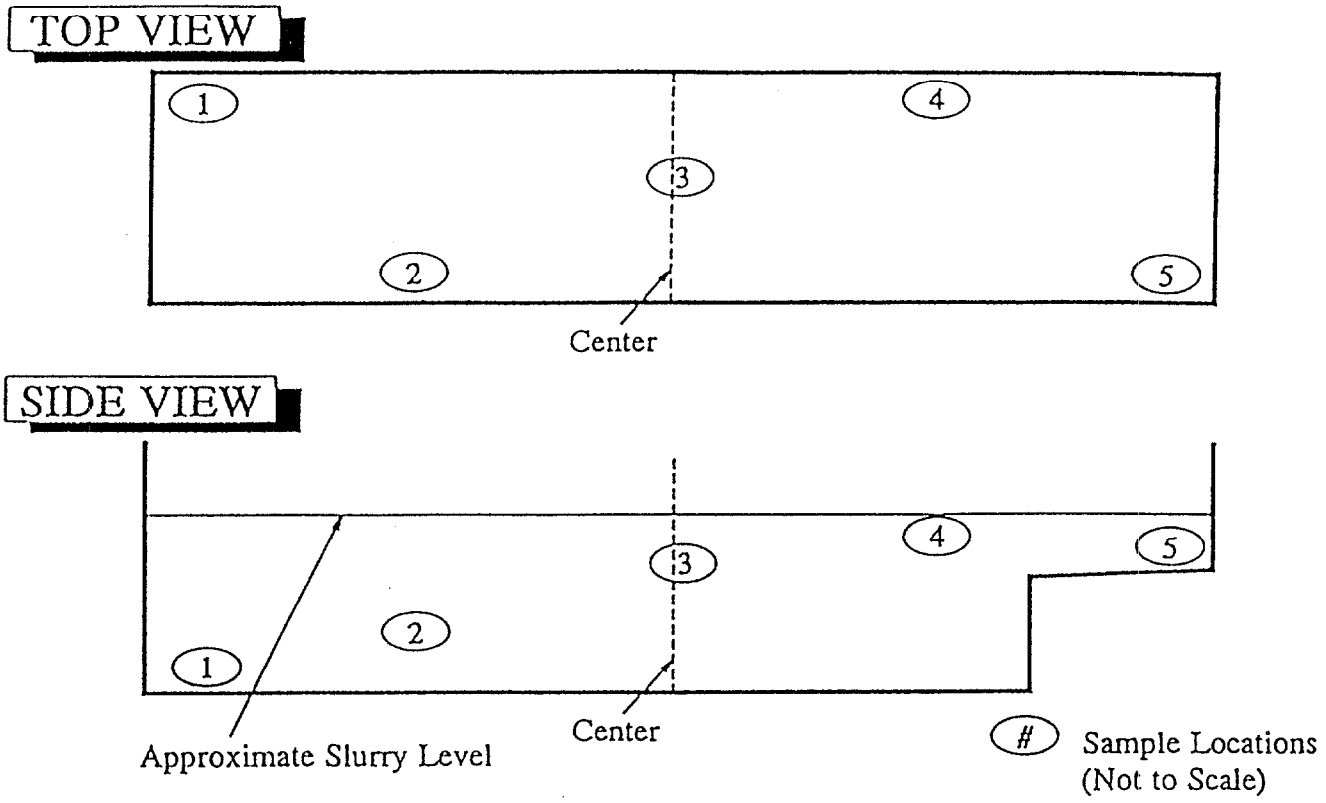


Figure 4-2. Daily Sampling Locations

of modified Method SW 846 8330 *(10)*. The average concentration of TNT in the feed soil, on a dry basis, was 1500 mg/kg with a range of 660 to 6,100 mg/kg. The 95% confidence interval around this average was 1200 to 1800 mg/kg. Upon arrival in the laboratory, the mid-point and the post-treatment slurry samples were phase separated, and the solid and liquid phases were analyzed separately. The mid-point samples showed that although the degradation of TNT was occurring, some locations within the bioreactor were above the State mandated treatment limit of 57 mg/kg with two aliquots from a single sample being much higher than encountered in pre-treatment analysis. It was postulated that "nuggets" of TNT were present in the soil that had not been captured during the pre-treatment sampling and analysis episode. The post-treatment sampling was initiated 9 months after loading of the bioreactor. A plot of the approximate degradation of TNT for the first 5 months of the treatment period at location 1 is given in Figure 4-3. The results from the final stage of sampling showed the average slurry concentration of TNT within the bioreactor was 8.7 mg/kg, on a dry basis, with a range of 0.005 mg/kg to 300 mg/kg.

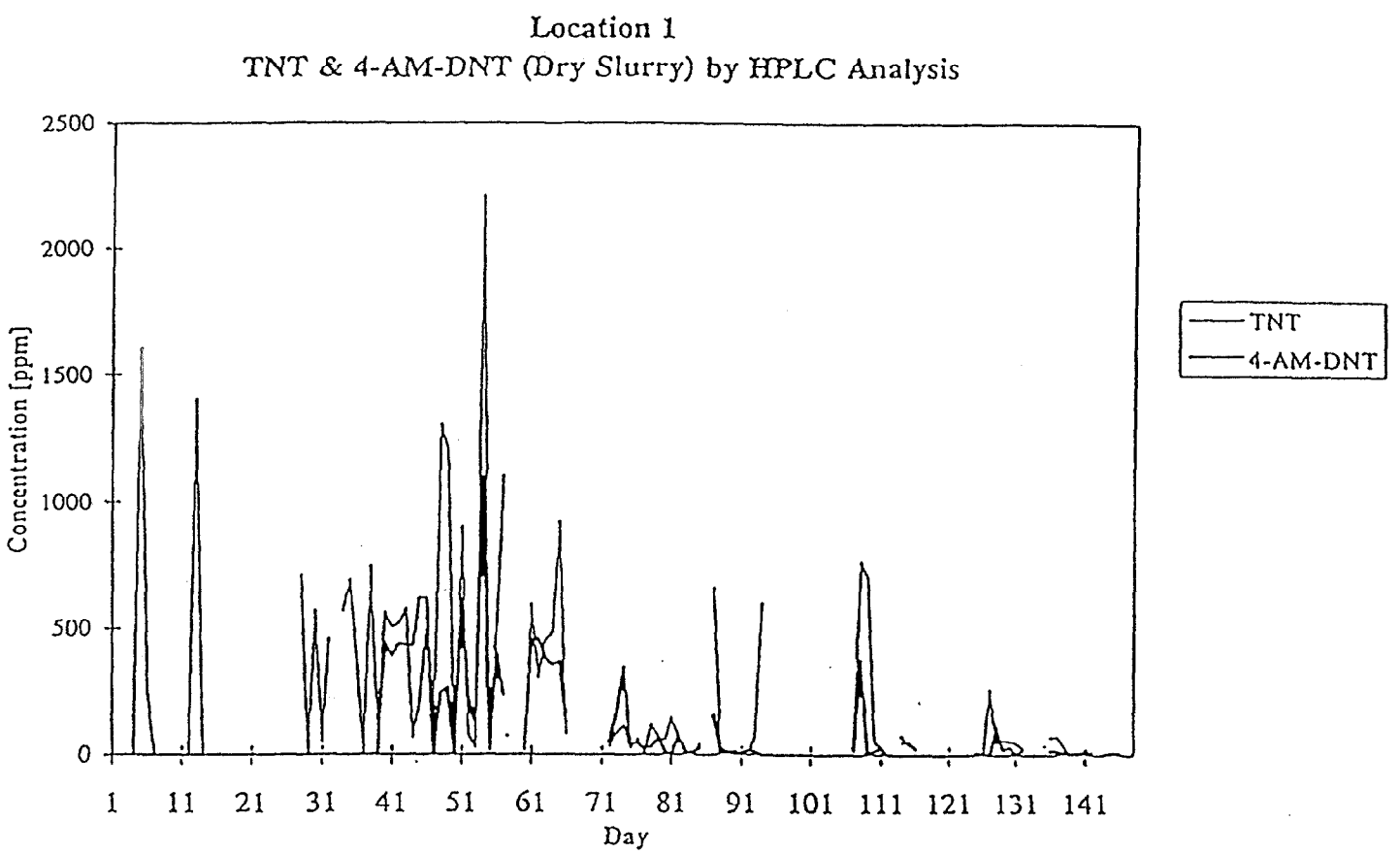


Figure 4-3. Daily Sampling Results for Location 1

This gives a Removal efficiency of 99.4%. The 95% confidence interval for this Removal Efficiency is 98.3% to 99.9%. The 95% confidence interval was determined using a bootstrap-based replication approach. This statistical method determines 10,000 alternate removal efficiencies then selects the 2.5 and 97.5th percentiles as the bounds for the confidence interval. This approach is further explained in the companion Technology Evaluation Report (TER).

Throughout the course of treatment, known intermediate compounds from the degradation of TNT were found during analysis. These known intermediate compounds are amino and diamino derivatives, 2,4,6-trihydroxytoluene, and p-cresol. The levels of these intermediate compounds were found to rise at the beginning of treatment and then decline significantly as remediation progressed. At the completion of treatment, the level of intermediate compounds was below the MDNR requirement that the total sum of

intermediate compounds at each location be below 2.5 mg/kg. The method of analysis for the quantification of the intermediate compounds was the same as for the TNT analysis but using a C18 column. A plot of the 4-amino-dinitrotoluene intermediate compound until the approximate mid-point of treatment (day 156) for location 1 is also given in Figure 4-3.

Analysis of 3 samples from the negative process control before, and 3 samples after treatment indicate that the TNT in the test soil did not naturally degrade during the treatment process. The average TNT concentration in the pre-treatment samples was 1,100 mg/kg as compared to the post-treatment negative control average of 1,300 mg/kg. Statistically, based on the three samples for each sampling phase, these quantities are the same, indicating that the TNT did not naturally degrade without the assistance of the bioremediation process.

Pesticides and Herbicides: Pre-treatment soil and make-up water samples were collected and analyzed for pesticides using SW-846 Method 8080 and for chlorinated herbicides using SW-846 Method 8150. These samples were taken and analyzed to determine if the toxicity tests would be relevant and that the presence of any pesticide or herbicide could lead to inconclusive results. Based upon the analysis of these samples, no significant quantities of these analytes were detected. It was decided not to analyze the post-treatment samples for these compounds.

Metals: Pre-treatment soil and make-up water samples were analyzed for ICP metals using SW-846 Method 6010. Samples were also analyzed for mercury using SW-846 Method 7470/71. Metals concentrations in the pre-treatment soils and make-up water were at levels generally found in natural soils and potable water, and were not thought to be toxic to the microorganisms. Although the post-treatment slurry samples were collected, they were only analyzed for lead to determine if bioconcentrating of this element had occurred. Other metals concentrations were not expected to change due to remediation. Table 4-1 presents a summary of the pre-treatment metals data for the soil and the make-up water. As can be seen from the Table any bioconcentration of the lead is not immediately apparent.

Toxicity: The toxicity tests were performed simultaneously on the pre- and post-treatment soils (slurry) to determine if the relative toxicity of the soil had changed because of the degradation of TNT. A suite of toxicity tests which included vascular plant root elongation, seedling survival and growth, and earthworm survival and reproduction were used to evaluate the efficacy of the J.R. Simplot

Table 4-1 Summary of Pre-Treatment Metals Data and Mid-Point Lead Data

Compound	Average Soil Concentration on a Dry Basis (mg/kg)	Average Make-Up Water Concentration (µg/L)	Average Slurry Midpoint Solid Phase Conc. (dry basis) (mg/kg)
Antimony	<11.9	<60	
Arsenic	<39.7	<200	
Barium	83.1	<200	
Berylium	<1.0	<5.0	
Cadmium	<1.0	<5.0	
Calcium	48,900	19,700	
Chromium	16.0	<10.0	
Cobalt	<9.9	<50.0	
Copper	8.5	<25.0	
Iron	14,900	19,700	
Lead	42.1	<100	31.7
Magnesium	2,100	16,100	
Manganese	262	424	
Mercury	<.10	<.20	
Molybdenum	<13.3	<67.0	
Nickel	10.6	<40.0	
Potassium	528	3,750	
Selenium	<59.5	<300	
Silver	<2.0	<10.0	
Sodium	<400	22,900	
Titanium	<99.2	<500	
Vanadium	24.2	<50.0	
Zinc	49.8	30.6	

bioremediation process in soils contaminated with TNT. This battery of tests was conducted on three treatment phases (reference, pre-, and post-treatment) of the three environmental matrices of primary interest: soil, solid phase of the slurry (slurry), and liquid phase of the slurry (eluate). However, no post-treatment soil (only slurry) was available for testing. To allow for comparisons between pre-treatment and post-treatment, a pre-treatment slurry was constructed. The pre-treatment slurry was prepared by mixing pre-treatment soil, make-up water, and treatment buffers in the same ratios as during the demonstration. The pre-treatment and post-treatment slurries were each allowed to settle into two phases, the eluate decanted into separate containers and the remaining soil dried to approximately the same dryness as the pre-treatment soil. The companion Technology Evaluation Report (TER) refers to these two separate phases as the post-treatment slurry and the post-treatment eluate. The vascular plant toxicity testing utilized alfalfa, red clover, cucumber, lettuce and penewawa wheat. The earthworm toxicity tests utilized the red worm. Each of the test species is routinely used in the evaluation of contaminated soils.

The Simplot bioremediation process successfully reduced the toxicity of the TNT-contaminated soil. The reduction in toxicity was evident from earthworm survival and reproduction. Concentration-response relationships also were generally observed in the toxicity tests during dilution series testing of the soils, solid phase of the slurry, and liquid phase of the slurry. The comparison of the toxicity test results for the soils, solid phase of the slurry, and liquid phase of the slurry supports the contention that the contaminant(s) in the site soil have a greater affinity for the particle phase than for the aqueous phase.

In all of the 100% reference and pre-treatment soils, the endpoints of interest for a particular test species was depressed in the pre-treatment soil relative to the reference soil and the negative controls. For example, survival of the five plant species during early seedling and growth tests was approximately 79% or greater in the negative controls, 46-94% in the reference soil but only 0-54% in the pre-treatment soil. Similarly, for all five plant species, measures of growth (i.e. mean shoot length and weight, total plant weight) were depressed in the pre-treatment soil relative to both negative control and reference soil. This pattern of results was also evident in earthworm survival and reproduction in pre-treatment soil when compared to negative controls and reference soil.

Evaluation of the test results for the 100% reference, pre-treatment, and post-treatment solid phase of the slurry indicated that the solid phases were about equally toxic to the five plant species relative to the

negative controls. The bioremediation process appeared to slightly reduce the toxicity of the post-treatment solid phase, although plant survival and growth among species was still depressed relative to the negative controls. Wheat was somewhat less affected by the toxicity of the pre-treatment slurry than were the other plant species. Earthworm survival was reduced in the pre-treatment slurry relative to all other treatments and reproduction was completely inhibited in the reference and the pre-treatment slurries. The Simplot bioremediation process decreased the toxicity of the post-treatment slurry to the earthworm both in terms of survival and reproduction although reproduction was still inhibited in the post-treatment slurry relative to the negative control.

In general, no effects were observed on survival or growth of the five plant species during early seedling tests of reference, pre-treatment, and post-treatment liquid phase of the slurry (eluate). Results of these tests were generally comparable to the results obtained with the negative controls. In contrast, root elongation tests of eluates conducted with the five plant species indicated that reference and pre-treatment eluates were toxic relative to both post-treatment eluate and negative controls. The bioremediation process effectively reduced the eluate effects observed on the five plant species in the root elongation test. Neither pre-treatment nor post-treatment eluate appeared to have any obvious effect on the earthworm survival or reproduction. The reference eluate exhibited toxicity to the earthworm, both in terms of survival and reproduction.

Sterile Process Control: Immediately after collection, the sterile process control was shipped to the laboratory for sterilization using gamma radiation. The sterile control was a slurry collected directly from the bioreactor (day 0). The sterile control did not receive sufficient dosage of gamma radiation to fully sterilize the control. This was identified after culture counts performed on the sterile process control detected the presence of the TNT degraders. The sample could not be re-irradiated because of the time lapse encountered and because of problems with the radiation source equipment at the laboratory.

4.4.2 Physical Analyses

Prior to treatment in the bioreactor, the soil was screened to separate out material greater than 15.9 mm (0.625 in) in diameter. Particle size distribution was determined for the soil both before and after the screening process. Atterberg limits were also determined for the soil before and after the screening process. The soil was determined to be a clayey gravel with sand. The density of the screened soil was

determined to be 1.4 g/cm^3 (87 lbs/ft^3). Density data were used to determine the total mass of soil treated.

4.5 Process Residuals

Three process waste streams were generated by implementation of the J.R. Simplot Ex-Situ Bioremediation Technology. These streams were the treated soil, the treated liquid, and the rocks and debris with diameters greater than 15.9 mm (0.625 in). The Missouri Department of Natural Resources (MDNR) established a clean-up level for TNT and known intermediate compounds below which the slurry no longer presented a hazard to human health and, therefore, would no longer be considered hazardous. After treatment in the bioreactor at Weldon Spring Ordnance Works (WSOW), the TNT concentrations in the treated soil and liquid were below the required treatment limits with exception of one soil location within the bioreactor. In all cases, the level of total process intermediate compounds was below the MDNR limit, as noted in Section 4.4.1 of this report. The treated slurry was then placed within lined pits in the excavated area. The ultimate disposal for TNT contaminated soils at the WSOW is by on-site incineration. In states where clean-up levels have not been established or when the clean-up levels have not been met, disposal of the soil at a RCRA-permitted facility may be necessary. If nitroaromatic compounds other than TNT are remediated, then disposal of the soil at a RCRA-permitted facility is only required if components of the wastes are listed or the material has hazardous waste characteristics.

A water/ethanol mixture may be used to wash the TNT from the separated rocks and debris. This was not performed by the J.R. Simplot Company during the Demonstration Test. When the percentage of oversize material becomes excessive and becomes a logistical problem, a separate soil or rock washing vendor may provide assistance in this task. The rinse water/ethanol mixture can then be added to the bioreactor with the make-up water to be remediated by the process. Another alternative is to crush the oversize debris to the required size and then add it to the bioreactor for remediation. After treatment in the bioreactor at the WSOW, the TNT concentration in the water phase was below the regulatory limit set by MDNR. The slurry was added to the lined pits allowing the liquid phase to flow through a sand filter and a carbon canister into adjacent areas. The spent carbon was treated as hazardous waste in this instance. In instances where ethanol is not used to wash the oversized debris, the wastewater can be

disposed through a publicly owned treatment works (POTW), assuming treatment standards have been met and the appropriate permits have been obtained.

The untreated rocks and debris, if not washed or crushed, may present a disposal problem. During the Demonstration Test, no rocks and debris greater than 15.9 mm (0.625 in) in diameter were washed or treated. For full-scale remediation when material greater than 38 mm (1.5 in) in diameter represents a high percentage of the excavated soil and not placed in the treatment process, the material must be transported off-site for disposal at a RCRA-permitted facility.

SECTION 5

OTHER TECHNOLOGY REQUIREMENTS

5.1 Environmental Regulation Requirements

Before implementing the J.R. Simplot Ex-Situ Bioremediation System, state regulatory agencies may require a number of permits to be obtained. A permit may be required to operate the system. A permit is required for storage of contaminated soil in a waste pile for any length of time and for storage in drums on-site for greater than 90 days. At the conclusion of treatment, permits may be required to discharge the wastewater to a publicly owned treatment works (POTW). A National Pollutant Discharge Elimination System (NPDES) permit may be required to discharge into surface waters. If air emissions are generated, an air emissions permit will be necessary. If off-site disposal of contaminated waste is required, the waste must be taken off-site by a licensed transporter to a permitted landfill.

Section 2 of this report discusses the environmental regulations that apply to this technology. Table 2-1 presents a summary of the Federal and state ARARs for the J.R. Simplot Ex-Situ Bioremediation Technology.

5.2 Personnel Issues

For pre-treatment operations (excavation, assembly, and loading), the number of workers required is a function of the volume of soil to be remediated. During the Demonstration Test, three workers and one supervisor were required for all operations through loading of the bioreactor. Once the reactor is loaded, a Simplot employee familiar with the system and any contaminant-specific requirements will fine-tune the system to ensure that appropriate operating conditions are established and maintained. During treatment, only one technician is required to operate the J.R. Simplot Ex-Situ Bioremediation System. This technician will be trained by a Simplot supervisor. The training will be specific to the J.R. Simplot Ex-Situ Bioremediation System. Treatment will take place 24 hours a day; however, it is anticipated that the technician will only be present for approximately one hour each day. During this time, all system parameters will be checked and any required modifications will be made. If necessary, the system may operate unattended for several days at a time. The same conditions apply for the lined, in-ground pits.

For the larger, modular bioreactors, eight workers are required for 16 hours to erect each bioreactor, and 12 workers are required for 16 hours to install the liner for each bioreactor. Two technicians are required for 8 hours a day, 5 days a week during treatment.

The health and safety issues for personnel using the Simplot system for waste treatment are generally the same as those that apply to all hazardous waste treatment facilities. The regulations governing these issues are documented in 40 CFR 264 Subparts B through G, and Subpart X.

Emergency response training for operations of the J.R. Simplot Ex-Situ Bioremediation System is the same as the general training required for operation of a treatment, storage, and disposal (TSD) facility as detailed in 40 CFR 264 Subpart D. Training must address fire-related issues such as extinguisher operation, hoses, sprinklers, hydrants, smoke detectors and alarm systems. Training must also address contaminant-related issues such as hazardous material spill control and decontamination equipment use. Other issues include self-contained breathing apparatus use, evacuation, emergency response planning, and coordination with outside emergency personnel (e.g., fire/ambulance).

For most sites, personal protective equipment (PPE) for workers will include gloves, hard hats, steel-toed boots, and Tyvek® suits. Depending on contaminant types and concentrations, additional PPE may be required. Noise levels should be monitored during excavation and pre-treatment screening, homogenization, and loading activities to ensure that workers are not exposed to noise levels above a time-weighted average of 85 decibels, over an 8-hour day. If operation of the J.R. Simplot Ex-Situ Bioremediation System increases noise levels above this limit, workers will be required to wear additional protection.

5.3 Community Acceptance

Potential hazards related to the community include exposure to volatile pollutants (if present) and other particulate matter released to air during soil excavation and handling. Air emissions can be managed by watering down the soils prior to excavation and handling, and covering the stockpiled soil with plastic. Depending on the scale of the project, the biodegradation process may require contaminated soils to remain stockpiled on-site for extended periods of time. This could expose the community to airborne

emissions for several months. Community exposure to stockpiled soils may be minimized by excavating in stages, limiting the amount of soil excavated to the amount of soil that can be treated at once.

The J.R. Simplot potato-processing starch byproduct used as a carbon source at the onset of treatment may be stored in 208-L (55-gal) drums on-site. Once the drums are opened, the potato-processing starch by-product gives off a foul odor in the immediate vicinity. This odor intensifies over time as the starch by-product ferments in the drums. The odor may be minimized by storing the drums in a shaded area to reduce the rate of fermentation. Keeping the drums sealed when not in use will also reduce the odor that escapes into the ambient air. However, the vapor pressure will build up in the drum and occasional venting will be necessary.

During bioremediation, the treatment slurry may also give off a foul odor caused by the enhanced microbial activity. The odor is not pervasive and only penetrates airspace in the immediate proximity of the treatment area; covering the bioreactor minimizes this odor.

Noise may be a factor to neighborhoods in the immediate vicinity of treatment. Noise levels may be elevated during excavation, screening, and homogenization since heavy equipment is used for these activities. During actual treatment the noise generated by the bioreactor and associated equipment is expected to be minimal.

SECTION 6

TECHNOLOGY STATUS

This section discusses the experience of the developer in performing treatment using the J.R. Simplot Ex-Situ Bioremediation Technology. It also examines the capability of the developer in using this technology at sites with different volumes of contaminated soil.

6.1 Previous Experience

The demonstration performed at the WSOW is the second demonstration to evaluate this technology for the destruction of nitroaromatic compounds. The first demonstration was performed at Bowers Field, near Ellensburg, WA. The contaminant of interest during this successful demonstration was the RCRA listed herbicide, dinoseb (P020). Dinoseb was reduced from 27.3 mg/kg to below the analytical detection limit in less than 23 days. This site is to undergo full-scale remediation using the Simplot process in the Spring of 1995.

The J.R. Simplot Company has no experience in the remediation of contaminated sites. To overcome this hurdle, Simplot intends to form partnerships with respected environmental remediation companies to implement this technology. For the two SITE Demonstrations, Envirogen Inc. has teamed with Simplot to provide the necessary expertise in performing full-scale operations. This company is working with Simplot for the full remediation at the Bowers Field Site.

The University of Idaho, in cooperation with the J.R. Simplot Company, have ongoing research programs to design improvements in the Simplot process and expand the applicability of this technology to specific sites and to additional compounds. Further work is being conducted to develop an in-situ process for subsurface soils and groundwater. Currently, treatability studies are being performed on soil from sites contaminated with TNT and other explosives in addition to sites contaminated with dinoseb. The Idaho Department of Environmental Quality has approved the use of the process at a dinoseb site neat Pocatello, Idaho. Approval from the California Department of Toxic Substances is required before the process can remediate a dinoseb contaminated site in Reedley, California. Field-scale remediation at Reedley has proven effective and it is anticipated that full-scale remediation will begin in the near future.

Additional laboratory treatability studies are being performed using the Simplot process on explosives-contaminated soil from several U.S. Navy bases by the Corps of Engineers Experimental Station in Vicksburg, MS. Laboratory studies are being used to determine the suitability of the process to treat explosive-contaminated soil from a former ordnance works near Mead, NE. Additional in-ground pits are being constructed for testing the process on soil contaminated with explosive compounds at Bangor Submarine base near Seattle, WA.

6.2 Scaling Capabilities

To date, the two SITE Demonstrations represent the largest scale of remediation performed using the J.R. Simplot Ex-Situ Bioremediation Technology. During the demonstrations, a small portable bioreactor was used to degrade 30 m^3 of dinoseb-contaminated soil in Ellensburg, WA and 23 m^3 of TNT-contaminated soil in Weldon Spring, MO.

Simplot (in cooperation with an environmental remediation company) has proposed that the remediation of greater volumes of soil will require the use of in-ground, lined, excavated pits, or large erected modular tanks. A scenario has been proposed by Simplot in which the remediation of up to 7,646 m^3 (10,000 yd^3) could be accomplished. This scenario involves excavating a pit 1.52 m (5 feet) deep, double lining the pit with HDPE liner, and using this as the bioreactor. Alternatively, remediation can be realized involving the rotating use of four 3,800,000-L (750,000-gal) tanks. Each tank would be lined with a 30-mil liner and used to remediate two 956 m^3 (1,250 yd^3) batches of soil. It is assumed that the remediation of each batch of soil would take approximately a similar remediation time as required during the SITE Demonstration. The maximum rock size that could be handled would be 38.1 mm (1.5 in) in diameter; all larger rocks would undergo washing or be crushed to this diameter.

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APPENDIX A

VENDOR'S CLAIMS

This appendix was generated and written solely by the J.R. Simplot Company. The statements presented herein represent the vendor's point of view and summarize the claims made by the vendor, the J.R. Simplot Company, regarding their Ex-Situ Bioremediation Technology. Publication herein does not represent the EPA's approval or endorsement of the statements made in this section; the EPA's point of view is discussed in the body of this report.

A.1 Introduction

The Simplot Bioremediation Process offers a bioremediation alternative to cleaning soils and water contaminated with nitroaromatics. Nitroaromatics have become serious environmental contaminants at both private and military locations nationwide. Examples of nitroaromatic contaminants include nitortoluene explosives, as well as many pesticides, including dinoseb, a herbicide banned because of health concerns.

The Simplot Process was demonstrated to degrade TNT (2,4,6-trinitrotoluene) and its degradation intermediate compound to acceptable cleanup levels specified by the Federal government. The Simplot process is an anaerobic bioslurry process for the degradation of nitroaromatic compounds in soil or aqueous phases. In the demonstration, the Simplot Process was used to clean soil contaminated with the explosive TNT, a National Priorities List contaminant.

The Simplot Process was demonstrated by the J.R. Simplot Company at the Weldon Spring Ordnance Works in Weldon Spring, Missouri. TNT contamination had persisted at this site since the 1940's. TNT wad degraded to a slurry concentration of 8.7 ppm from a beginning slurry concentration of 1500 ppm, resulting in overall reduction greater than 99.4%

Optimal temperatures for The Simplot Process have been determined to be between 35°C to 37°C. Because the treatment was not begun until late Fall, the average ambient temperature was below this.

The Simplot Process was entirely effective, even with sub-optimal temperatures resulting in degradation of TNT within 5 months.

The Simplot Process, developed by the University of Idaho and the J.R. Simplot Company, with patents pending, is licensed exclusively to the J.R. Simplot Company.

A.2 Process

The Simplot process begins when contaminated soil is placed in a bioreactor with specially prepared water in an one-to-one ratio by weight. Water is prepared by adding nutrients, pH buffers, and a special carbon source (a Simplot potato processing byproduct). Addition of the excess carbon source to the reactors results in the consumption of dissolved oxygen by aerobic bacteria, rapidly establishing anaerobic conditions. The process is illustrated on the next page.

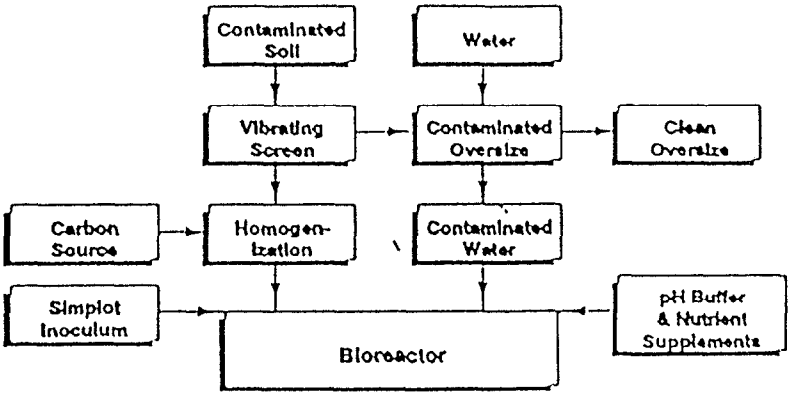
Before soil is added to the bioreactor, a consortium of enhanced nitroaromatic-degrading anaerobic bacteria is introduced to the conditioned water, to increase the rate of nitroaromatic degradation. The enhanced anaerobic bacteria are stimulated to grow and degrade dinoseb to short chain organic acids, without formation of potentially toxic polymerization products. After the treatment is complete and the soil is returned to site, aerobic bacteria can degrade the short-chain organic acids to CO_2 and water.

The Simplot Process has been demonstrated successfully on a variety of soil types, from sandy soils to tight clays. Rates of degradation are slightly delayed in heavier soil textures. The Simplot Process makes use of feasibility testing to optimize the rate of degradation for each site by altering inputs on a site-by-site basis.

A.3 Cost

Cost of the Simplot process is less than half the cost of thermal processes including incineration. Savings of transportation and related costs result because soil remains on site. Cost for a typical site can be as low as $250 per cubic yard. Costs are dependent on site characteristics and cost per cubic yard of soil will be lower with greater quantities.

The Simplot Process



A.4 Technical Information

This technology is designed to treat soils contaminated with nitroaromatic contaminants. Anaerobic microbial mixtures have been developed for the TNT and other explosives. These contaminants can be reduced to meet or exceed regulatory treatment levels in most soils. The proprietary inoculum used by the Simplot Process consists of a variety of microbial genera, developed at the University of Idaho through selection of anaerobic microbes that have been most effective in degrading nitroaromatic compounds.

Anaerobic microbial mixtures have been developed by the University of Idaho for Simplot for both the pesticide dinoseb (2-sec-butyl-4,6 dinitrophenol) and trinitrotoluene (TNT).

The consortium becomes active at redox potential of -200 mV or lower.

The initial step in the metabolism of nitroaromatic compounds is a reduction of the nitro substituents to amino groups, producing amino-nitro compounds. These intermediate compounds are further degraded to simple organic acids, and hydroxylated aromatics, which can be subsequently mineralized by indigenous bacteria.

A.5 Advantages

- TNT concentrations have been reduced by more than 99.4% using The Simplot Process, achieving regulatory cleanup levels.
- Complete anaerobic biodegradation of TNT is achieved without the formation (accumulation) of toxic intermediate compounds.
- Breakdown of TNT is complete, resulting in innocuous byproducts, mainly organic acids and carbon dioxide.
- TNT is degraded using The Simplot Process at temperatures considerably lower than is required for other biological remediation methods.
- Periodic mixing is sufficient for optimum degradation.
- The Simplot Process has been proven effective in the presence of other commonly found contaminants at military sites, including other explosives such as RDX, HMX, nitrotoluenes, and nitrobenzenes.
- The Simplot Process is a cost-effective alternative to traditional technologies for both large and small sites. Costs are often less than half of the cost to incinerate. Total costs are site-specific and determined by treatability studies.
- Remediated soils are rich in organic content and with high nutrient value, suitable for returning to the site.
- Liability is reduced because contaminated soil is remediated without being transferred off-site.
- Treatment of any contaminated site is completed within one season.

A.6 Limitations

- Each site must be individually assessed by treatability studies.
- Presence of co-contaminants may require additional processing, or may be unsuitable for the Simplot process.

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Environmental Protection Agency
National Risk Management
Research Laboratory, G-72
Cincinnati, OH 45268

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APPENDIX B
FIELD TEST KIT INFORMATION

ENSYS INC.
ENVIRONMENTAL PRODUCTS

TNT SOIL TEST SYSTEM

User's Guide

IMPORTANT NOTICE

The range of this test is between 1 and 30 ppm TNT/TNB/DNT. The relative standard deviation is 8% The least detectable concentration is 0.7 ppm.

This test system should be used only under the supervision of a technically qualified individual who is capable of understanding any potential health and environmental risks of this product as identified in the product literature. The components must only be used for the analysis of soil samples for the presence of TNT. After use, the kits must be disposed of in accordance with applicable federal and local regulations.

PHASE 1
TEST PREPARATION
READ ALL INSTRUCTIONS BEFORE PROCEEDING WITH THE TEST

ITEMS INCLUDED IN TEST KIT

- ☐ 2 Cuvette stopper plugs
- ☐ 1 Ampule cracker
- ☐ 20 Syringe filters
- ☐ 20 Wooden spatulas
- ☐ 20 Extraction jars
- ☐ 1 Bulb pipette
- ☐ 1 Developer solution
- ☐ 1 - 50mL graduated conical tube
- ☐ 1 TNT control ampule
- ☐ 20 - 30cc syringes
- ☐ 20 Weigh boats

ITEMS NOT INCLUDED IN TEST KIT

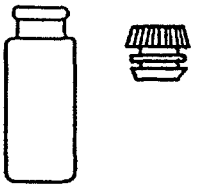
- ☐ 2 matched HACH cuvettes
- ☐ Paper towels
- ☐ Disposable gloves
- ☐ Acetone
- ☐ Hach DR/2000
- ☐ Calculator
- ☐ Waste container
- ☐ Balance

READ BEFORE PROCEEDING

- You must dry the sample prior to analysis.
- It is recommended that a control be run each day. See page 8 for instructions.
- The Hach DR/2000 is designed to turn off after a few minutes of inactivity. Press the "READ/ENTER" key every few minutes to prevent DR/2000 from turning off. If DR/2000 turns off, use Reference cuvette to rezero. Newer DR/2000 models have an overide "constant on" feature that allows the machine to run indefinitely. See p. 12 of HACH DR/2000 User's manual.

If you are using the TNT test in conjunction with the RDX test it is important to save your sample extracts after analysis. They will be used in the RDX test. Remember to cap the extracts tightly after use. An RDX kit without extraction set-ups can be purchased specifically for this purpose.

PHASE 1
TEST PREPARATION
READ ALL INSTRUCTIONS BEFORE PROCEEDING WITH THE TEST



CLEAN CUVETTES

1a Fill 2 Hach matched cuvettes with approximately 5 mL water.

1b Cap each with cuvette stopper plug and, holding plug in place, shake vigorously for 3 seconds.

1c Empty into waste container.

1d Fill cuvettes with approximately 5 mL acetone.

1e Cap each with cuvette stopper plug and, holding plug in place, shake vigorously for 3 seconds.

1f Empty into waste container.

1g Repeat acetone wash (steps **1d - 1f**).

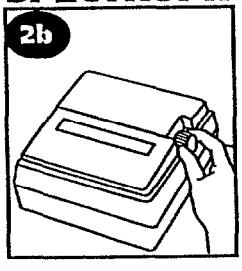
1h Wipe outside of cuvette with paper towels. Take care to especially clean the side labeled "25 mL" and the side opposite.

PHASE 1
TEST PREPARATION
READ ALL INSTRUCTIONS BEFORE PROCEEDING WITH THE TEST

READ BEFORE PROCEEDING

- Designate a "Reference" and "Sample"cuvette.

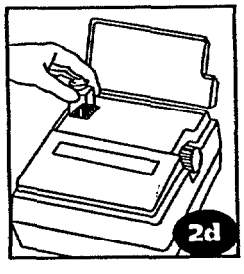
SPECTROPHOTOMETER PREPARATION



2a Turn on Hach DR/2000. The instrument will read "SELF-TEST" followed by "Method?". Select Method "0" and press the "READ/ENTER" key.

2b Rotate the wavelength dial until the small display shows: 540 nm.

2c Fill both cuvettes with acetone to the 25 mL line.



2d Insert "Reference" cuvette into cell holder on Hach DR/2000 with side marked "25 mL" on the right.

2e Close light shield and press "CLEAR/ZERO" key to establish the reference. The display will read "WAIT" and then "0.000 Abs.".

2f Remove the "Reference" cuvette and place the "Sample" cuvette in the cell holder.

2g Press the "READ/ENTER" key and record the absorbance on the worksheet as "$Abs_{background}$".

2h If reading is greater than 0.002 in magnitude (+ or -), clean cuvettes and redo steps **2a - 2g**.

2i Empty acetone from "Sample" cuvette into waste container.

Cuvette

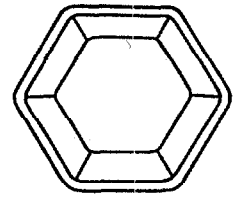
PHASE 2

EXTRACTION & PREPARATION OF THE SAMPLE

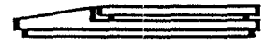
READ ALL INSTRUCTIONS BEFORE PROCEEDING WITH THE TEST

READ BEFORE PROCEEDING

- Sample should be mixed to ensure a homogeneous sample.
- Dry sample to obtain <10% moisture.



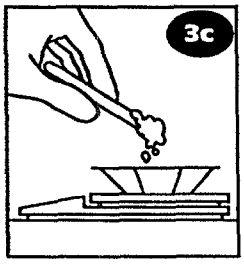
Weigh Boat



Pan balance

Wooden spatula

WEIGH SAMPLE



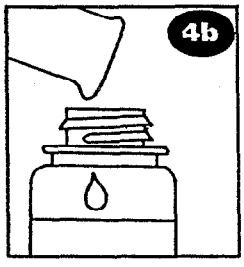
3a Place an unused weigh boat on pan balance.

3b Press ON/MEMORY button on pan balance. Balance will beep and display 0.0.

3c Weigh out 10+/- 0.1 grams of soil.

3d If balance turns off prior to completing weighing, use empty weigh boat to retare, then continue.

EXTRACT TNT



4a Measure 50 mL acetone in the 50mL graduated Conical tube.

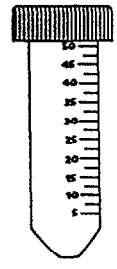
4b Pour acetone into an extraction jar.

4c Using wooden spatula, transfer 10 grams of soil from weigh boat into extraction jar.

4d Recap extraction jar tightly and shake vigorously for three minutes.

4e Allow to settle for five minutes.

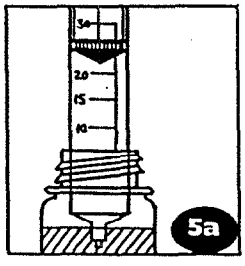
Repeat steps **3a - 4e** for each sample to be tested.



50mL Graduated Conical Tube

Extraction Jar

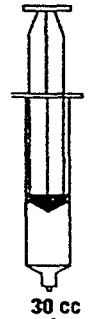
FILTER SAMPLE



5a Place tip of 30 cc syringe into liquid above the sediment layer in the extraction jar and draw up 25 mL of the sample.

5b Screw the syringe filter onto the end of the syringe.

5c Press the plunger firmly and dispense the sample into the "Sample" cuvette.



30 cc syringe

Syringe filter

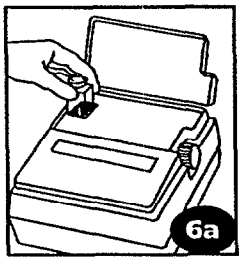
Cuvette

PHASE 3

SAMPLE ANALYSIS

READ ALL INSTRUCTIONS BEFORE PROCEEDING WITH THE TEST

READ SAMPLE



6a Place the "Sample" cuvette in the cell holder.

6b Press the "READ/ENTER" key and record the absorbance on the worksheet as "$Abs_{initial}$".

6c Remove the "Sample" cuvette from the cell holder.

6d Add 1 drop of Developer Solution

6e Cap the "Sample" cuvette and shake vigorously for 3 seconds.

6f Remove the cuvette stopper and place the "Sample" cuvette in the cell holder.

6g Press the "READ/ENTER" key and record the absorbance on the worksheet as "Abs_{sample}".

6h Clean cuvette between samples using procedure in steps **1a - 1h**.

Cuvette

PHASE 4
INTERPRETATION
READ ALL INSTRUCTIONS BEFORE PROCEEDING WITH THE TEST

INTERPRETATION OF RESULTS

7a Multiply the "$Abs_{initial}$" value for each sample by 4. Enter these values on the worksheet.

7b Subtract this value from the "Abs_{sample}" values for each sample and record on the worksheet.

7c Divide the adjusted sample value by 0.0323 and record on the worksheet. This value is the TNT concentration of the sample in parts per million.

$$TNT_{(ppm)} = \frac{Abs_{sample} - (Abs_{initial} \times 4)}{0.0323}$$

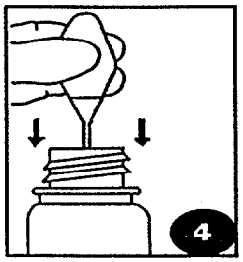
Note: For sample concentrations greater than 60ppm the sample extract should be diluted with acetone. After dilution the "$absorbance_{final}$" should be between 0.30 and 2.00.

CONTROL (QA/QC) CHECK

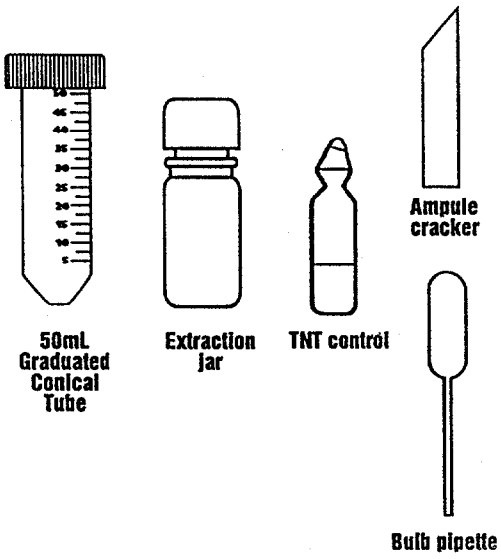
READ ALL INSTRUCTIONS BEFORE PROCEEDING WITH THE TEST

- The TNT control is optional but, it is recommended that it be run daily.

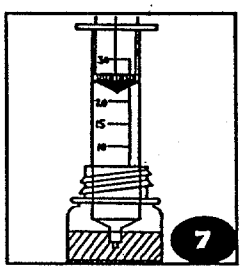
PREPARE CONTROL

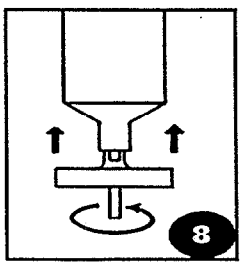


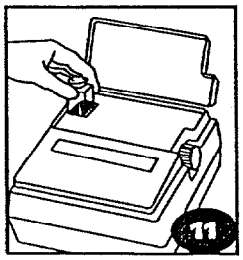
1. Measure 50 mL acetone in the 50mL graduated Conical tube.
2. Pour into extraction jar.
3. Open TNT control ampule by slipping ampule cracker over top, and then breaking tip at scored neck.
4. Transfer entire contents of TNT control ampule into extraction jar using bulb pipette.
5. Rinse TNT control ampule with acetone from extraction jar and dispense rinse back into the extraction jar.
6. Cap extraction jar and shake vigorously for 3 seconds.



ANALYZE THE CONTROL



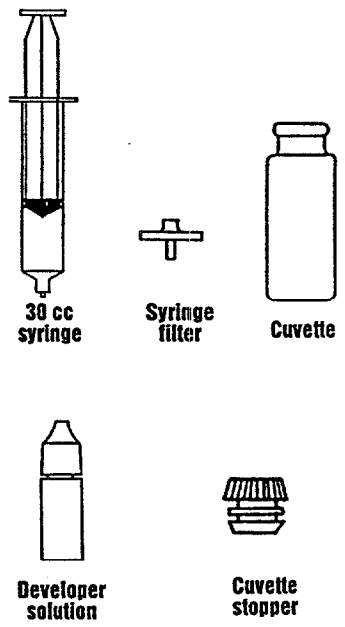




7. Place tip of 30 cc syringe in extraction jar and draw up 25 mL.
8. Attach syringe filter and dispense into "Sample" cuvette.
9. Add 1 drop of developer solution.
10. Cap the cuvette and shake vigorously for 3 seconds. **Immediately proceed to step 11.**
11. Remove the cuvette stopper and place in the cell holder.
12. Press "READ/ENTER" key and record the absorbance on the worksheet as "$Abs_{control}$".

    Absorbance must be between 0.307 - 0.373 for the test to be in control.

    If test is not in control, clean "Sample" cuvette, and then redo steps **7-12** using the remaining liquid from the extraction jar.
13. If test is in control clean "Sample" cuvette before proceeding with samples.



QUALITY CONTROL

READ ALL INSTRUCTIONS BEFORE PROCEEDING WITH THE TEST

System Description

Each TNT Soil Test System contains enough material to perform twenty complete tests.

The TNT Soil Test is divided into four phases. The instructions and notes should be reviewed before proceeding with the test.

Hotline Assistance

If you need assistance or are missing necessary Test System materials, call toll free: 1-800-242-RISC (7472).

Validation and Warranty Information

Product claims are based on validation studies carried out under controlled conditions. Data has been collected in accordance with valid statistical methods and the product has undergone quality control tests of each manufactured lot.

TNT-free soil and soil containing 1 ppm of TNT were tested with the EnSys TNT analytical method. The method correctly identified 95% of these samples. A sample that has developed less color than the standard is interpreted as positive. It contains TNT.

The company does not guarantee that the results with the TNT Soil Test System will always agree with instrument-based analytical laboratory methods. All analytical methods, both field and laboratory, need to be subject to the appropriate quality control procedures.

EnSys, Inc. warrants that this product conforms to the descriptions contained herein. No other warranties, whether expressed or implied, including warranties of merchantability and of fitness for a particular purpose shall apply to this product.

EnSys, Inc. neither assumes nor authorizes any representative or other person to assume for it any obligation or liability other than such as is expressly set forth herein.

Under no circumstances shall EnSys, Inc. be liable for incidental or consequential damages resulting from the use or handling of this product.

How It Works

Controls, Samples, and color-change reagents are added to cuvettes. The concentration of TNT in an unknown **Sample** is determined by evaluating how much color is developed.

Quality Control

Standard precautions for maintaining quality control:

- Do not use reagents or components from one Test System with reagents or components from another Test System.
- Do not use the Test System after its expiration date.
- The sample must be analyzed immediately after adding the Developer Solution.
- Results may not be valid if DR/2000 reading for **Control** is outside of the range of 0.307 - 0.373.

Storage and Handling Precautions

- Wear protective gloves and eye wear.
- Store kit at room temperature and out of direct sunlight (less than 80°F).
- If acetone comes into contact with eyes, wash thoroughly with cold water and seek immediate medical attention.
- Operate test at temperatures greater than 4° C/40° F and less than 39° C/100° F.
- After use, dispose of kit components in accordance with applicable federal and local regulations.

ON-SITE QUALITY CONTROL/QUALITY ASSURANCE RECOMMENDATIONS
EnSys RISC® TEST SYSTEM

Please read the following before proceeding with field testing.

SAMPLING

The result of your screening test is only as valid as the sample that was analyzed. Samples should be homogenized thoroughly to ensure that the 10 grams you remove for field testing is representative of the sample as a whole. All other applicable sample handling procedures should be followed as well.

PRIOR TO TESTING SAMPLES

Carefully follow the instructions in the User's Guide included with every test kit. This is the key element in obtaining accurate results. In addition, store your unused test kits at room temperature and do not use them past their expiration date (see label on each test kit).

INTERNAL TEST QC

One control is provided with each Kit to provide internal test system quality control. Test runs resulting in a number that falls outside of the specified range should be repeated to ensure valid conclusions.

QA/QC

The validity of field test results can be substantially enhanced by employing a modest, but effective QA/QC plan. EnSys recommends that you structure your QA/QC plan with the elements detailed below. These have been developed based on the data quality principles established by the U.S. Environmental Protection Agency.

A. **Sample Documentation**
   1. Location, depth
   2. Time and date of collection and field analysis

B. **Field analysis documentation** - provide raw data, calibration, any calculations, and final results of field analysis for all samples screened (including QC samples)

C. **Method calibration** - this is an integral part of EnSys tests; an RDX control analysis should be performed daily (see the instructions in the User's Guide)

D. **Method blank** - field analyze fresh acetone

E. **Site-specific matrix background field analysis** - collect and field analyze uncontaminated sample from site matrix to document matrix effect

F. **Duplicate sample field analysis** - field analyze duplicate sample to document method repeatability; at least one of every 20 samples should be analyzed in duplicate

G. **Confirmation of field analysis** - provide confirmation of the quantitation of the analyte via an EPA-approved method different from the field method on at least 10% of the samples; provide chain of custody and documentation such as gas chromatograms, mass spectra, etc.

H. **Performance evaluation sample field analysis (optional, but strongly recommended)** - field analyze performance evaluation sample daily to document method/operator performance

I. **Matrix spike field analysis (optional)** - field analyze matrix spike to document matrix effect on analyte measurement

FURTHER QUESTIONS?

EnSys technical support personnel are always prepared to discuss your quality needs to help you meet your data quality objectives. (919)941-5509 (OPTION 4)

TNT SOIL TEST - ABBREVIATED PROCEDURE

STEP	PROCEDURE
1	• Clean cuvettes • Zero the spectrophotometer at 540 nm
2	• Add 10 g soil and 50 ml acetone to extraction jar • Shake 3 minutes, let settle • Draw up 25 mL extract, filter into cuvette
3	• Read $Abs_{initial}$, record • Add 1 drop developer solution, shake • Read Abs_{sample}, record
4	• Multiply $Abs_{initial}$ by 4 • Subtract from Abs_{sample} • Divide by 0.0323 • $TNT_{(ppm)} = \frac{Abs_{sample} - (Abs_{initial} \times 4)}{0.0323}$

TNT SOIL TEST KIT WORKSHEET

$Abs_{background}$ _____ $Abs_{control}$ _____

1	2	3	4	5	6
SAMPLE #	$Abs_{initial}$	Abs_{sample}	$Abs_{initial}$ x4	Abs_{final} (Column 3 - Column 4)	TNT CONC ppm (Column 5/0.0323)

DR/2000 Spectrophotometer

Combines Stored Programs and Advanced Optics

- **More than 120 preprogrammed calibrations**
- **Store your own calibrations**
- **Updated ROM**

When you use the DR/2000, you can forget about constructing calibration curves. And mixing standards. And measuring reagents. Because we've done all that for you.

Using our convenient, premeasured reagents will save you more time. You'll appreciate the economy of ready-to-use solutions, PermaChem powder pillows, single-dose polyethylene powder pillows and vacuum-sealed ampuls.

More than 120 Preprogrammed Calibrations

Calibrations for over 120 commonly performed analyses are permanently stored in the DR/2000's ROM (read-only memory). Manual conversion of absorbance data to concentration values is eliminated. That means you won't have to prepare calibration curves. Enter the three-digit program number of the test you want to perform, insert the sample and read the results in concentration units on the digital display.

Store Your Own Calibrations

Customize your DR/2000 by adding up to 50 of your own calibrations to the instrument's permanent memory.

Update Capability

A few simple keystrokes are all it takes to add new Hach methods to your software. As new tests become available, you can add new testing procedures to your DR/2000.

New 3.2 Software With Latest Methods

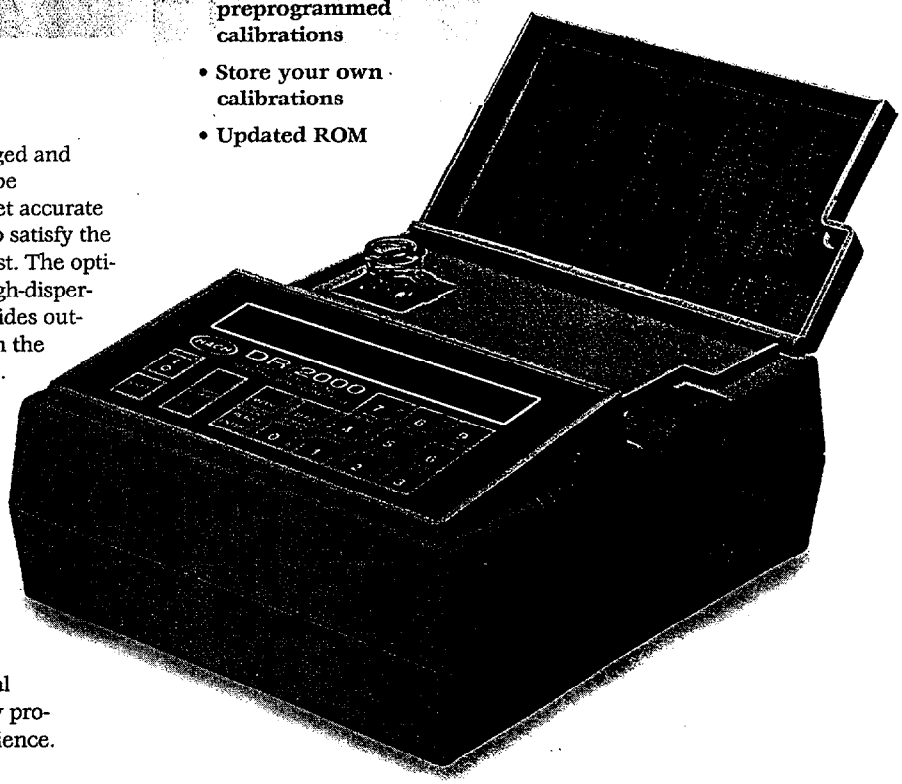
All new DR/2000 Spectrophotometers are now programmed with version 3.2 software, an important update that includes new Hach methods such as ultra-low range chlorine and ultra-low range hardness.

Rugged, High Quality Optics

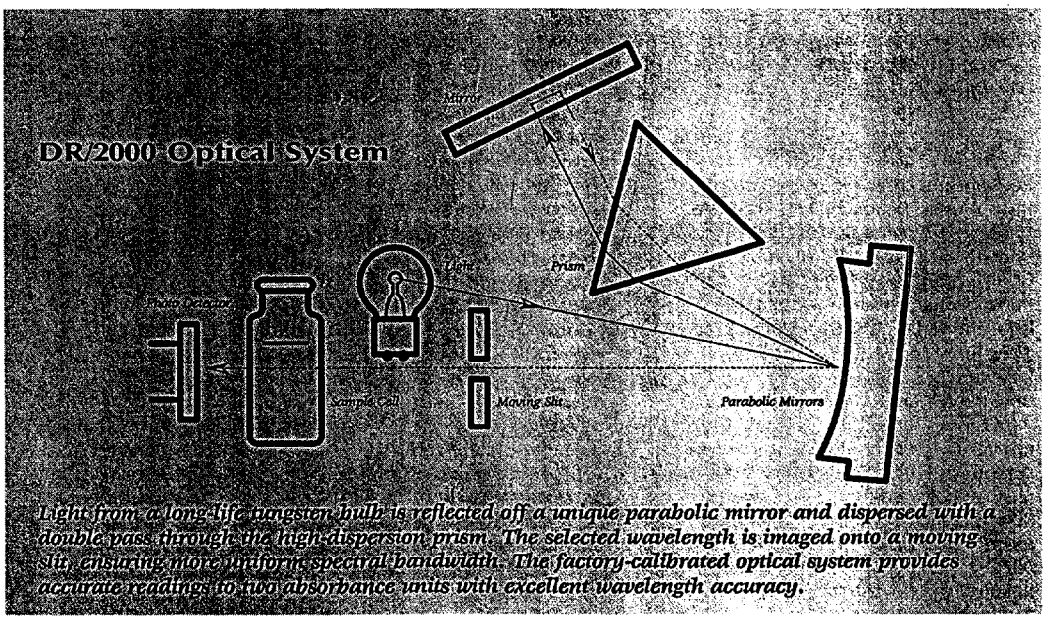
The DR/2000 is rugged and compact enough to be a field instrument yet accurate and stable enough to satisfy the most exacting analyst. The optical system uses a high-dispersion prism and provides outstanding precision in the 400 to 900 nm range.

Operates on Battery or Line Power

Use line power when you're in the laboratory. Or switch to battery operation for testing anywhere, anytime. An optional rechargeable battery provides added convenience.



The DR/2000 saves time and money in the laboratory or out in the field.



Light from a long life tungsten bulb is reflected off a unique parabolic mirror and dispersed with a double pass through the high-dispersion prism. The selected wavelength is imaged onto a moving slit, ensuring more uniform spectral bandwidth. The factory-calibrated optical system provides accurate readings to two absorbance units with excellent wavelength accuracy.

Computer Interface Capability

Connect the DR/2000 to a computer using a RS232 serial interface. Then use commonly available software programs to make permanent records of your data and generate written reports of your results.

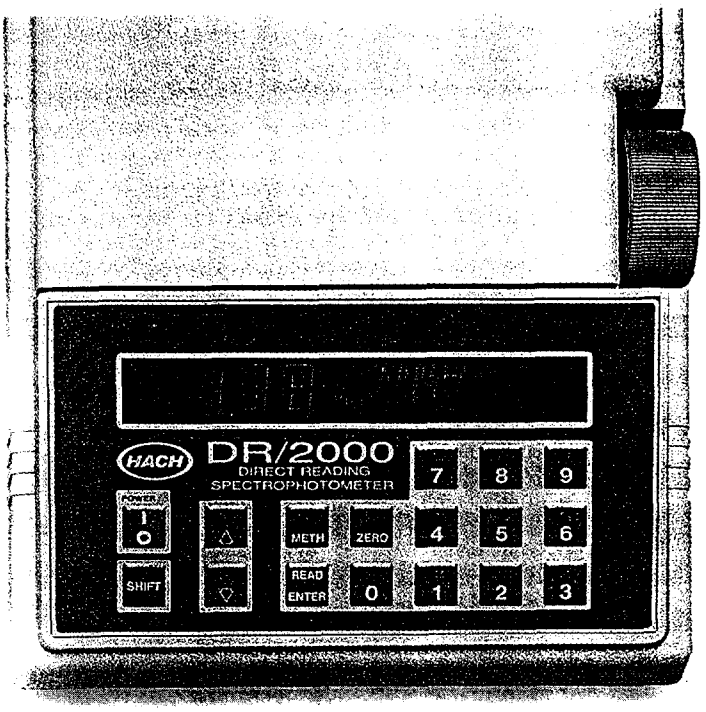
Multi-Language Prompting

Prompting messages in 14 languages (including English, French, German, Spanish, Italian, Portuguese, Dutch, Norwegian, Swedish, Danish, Finish, Turkish, Greek and Japanese) guide you step-by-step through stored procedures.

Do-It-Yourself Calibration Adjustment

To help you consistently obtain the best possible analytical answers, a Lamp Recalibration Filter Assembly is included with each new DR/2000 Spectrophotometer. Easy-to-follow instructions permit you to periodically verify the monochromator calibration accuracy and make adjustments if necessary.

DR/2000 Spectrophotometer



A few keystrokes are all it takes to select one of more than 120 preprogrammed methods.

Complete Procedures Manual*

Get accurate answers easily with step-by-step instructions. Each DR/2000 is accompanied by a 400-page procedures manual with step-by-step instructions for performing each test. The easy-to-follow directions are accompanied by over 1500 drawings, illustrating each step. These detailed instructions enable even inexperienced operators to get accurate results.

Each procedure also includes information on sampling and storage, checking accuracy, adjusting for interferences, and a listing of all the reagents and apparatus needed to run the test. Procedures for soil extraction, plant extraction, and other pretreatment procedures are also included.

- Procedure name
- Range with units of measure
- Approval of method by USEPA** if applicable
- Type of samples analyzed
- Clarification of USEPA approval (if needed)
- Name of method used
- Procedure step
- Keystrokes required
- Instrument display
- Additional information that may be applicable
- Illustration of procedure steps and instrument key strokes required

*Available in English, French, Spanish and German
**U.S. Environmental Protection Agency

Selectable Modes

Choose the photometric readout mode that suits your needs: concentration, absorbance or % transmittance.

Complete System for Analysis

A spectrophotometer is only as good as the system that supports it. That's why every DR/2000 is backed by Hach's simplified methods, premeasured reagents, step-by-step instructions and technical support .

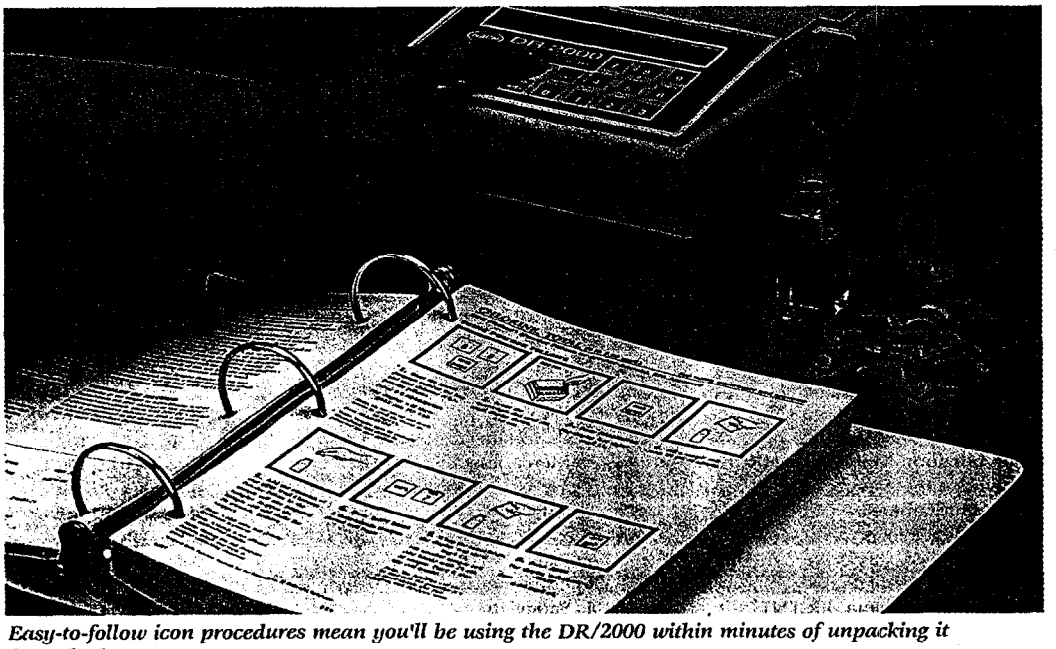
Specifications

Typical Use: Laboratory/portable
Wavelength Range: 400-900 nm
Wavelength Accuracy: ± 2 nm from 400-700 nm; ± 3 nm from 700-900 nm
Wavelength Resolution: 1 nm
Bandwidth: 12 ± 2 nm (@ 600 nm)
Stray Light: < 1.0%
Photometric Accuracy: ± 0.002 A from 0 to 1 A (@ 500 nm)
Optical System: Littrow prism, aspheric optics
Light Source: Gas-filled tungsten lamp
Bulb Life: 2000 hours
Detector: Silicon photodiode, UV enhanced
Operating Modes: Concentration, absorbance, % transmittance
Operating Temperature Range (ambient): 0-40 °C
System Diagnostics: Yes
Power Source: Selectable 110/220 Vac, 50/60 Hz, or rechargeable battery, or 6 D alkaline batteries
Battery Life: 1000 measurement cycles (rechargeable)
External Output: RS232 serial interface, 0-1 V analog
Display: LCD
Weight: 2 kg (4.4 lb)
Shipping Weight: 6.8 kg (15 lb)
Dimensions: 22 x 24 x 11 cm (8.75 x 9.5 x 4.38")

How To Order

44800-00 DR/2000 Spectrophotometer complete with matched pair of sample cells, AccuVac Adapter, 1-inch AccuVac Zeroing Cell, COD Adapter Kit, 1-inch sample cell, Outdoor Light Shield, Lamp Recalibration Filter Assembly, Dust Cover, Battery Holder, Battery Eliminator/Charger $1495.00

For more information, circle 4218.



Easy-to-follow icon procedures mean you'll be using the DR/2000 within minutes of unpacking it from the box.

TNT SOIL TEST

The TNT Soil Test is a wet chemistry, non-immunoassay, field-compatible test that provides quantitative results. The method was originally developed by Dr. Thomas F. Jenkins with the Army Corps of Engineers Cold Regions Research and Engineering Laboratory and funded by the Army Environmental Center.

The TNT Soil Test gives an accurate concentration value from 1 to 30 ppm. Higher sample concentrations can be quantified by dilution of the sample extract. A calibrator control is provided in each Test Kit.

The TNT Soil Test also effectively detects dinitrotoluene (DNT) at approximately the same concentrations:

Minimum Detection Levels	**2,4,6-trinitrotoluene**	**0.7 ppm**
	2,4-dinitrotoluene	**0.5 ppm**
	2,6-dinitrotoluene	**2.1 ppm**
	1,3,5-trinitrobenzene	**0.5 ppm**
	1,3-dinitrobenzene	**<0.5 ppm**
	tetryl	**0.9 ppm**
Format	**20 Test Kit**	
Analysis Time*	**10 minutes per sample**	
Sample Throughput	**10 samples per 40 minutes**	
Operational Temperature Range	**40°F to 100°F**	
Storage Temperature	**Room temperature**	
Shelf Life**	**24 months at 80°F**	
Regulatory Status	**EPA SW-846 draft Method**	
8515 to	**be promulgated in 1996**	
Confirmatory Laboratory Method	**EPA Method 8330**	

**For some matrices, air drying the soil samples may result in better TNT recovery and more reproducible data.*

**Guaranteed 2 months upon delivery. Call the Order Department for current kit shelf life.

APPLICATIONS

Industries:

Army Ammunition Manufacturing Facilities
Depots and Explosives Ordinances
Disposal Sites

- Delineation of soil contamination
- Monitoring remediation and treatment

LAB RESULT

RDX SOIL TEST

The RDX (hexahydro-1,3,5,-trinitro-1,3,5-triazine) Soil Test System is a wet chemistry, non-immunoassay, field-compatible test that provides quantitative results. The method was originally developed by Dr. Thomas F. Jenkins at the Army Corps of Engineers Cold Regions Research and Engineering Laboratory with funding by the Army Environmental Center.

The RDX Soil Test gives an accurate concentration value from 1 to 30 ppm. Higher sample concentrations can be quantified by dilution of the sample extract. A calibration control is provided in each Test Kit.

The RDX Soil Test also effectively detects HMX (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine) at approximately the same concentrations.

Minimum Detection Levels	**RDX 0.8 ppm** **HMX 2.4 ppm** **PETN 1.0 ppm**
Nitroglycerine	**8.9 ppm**
Nitroguanadine	**10.1 ppm**
Nitrocellulose	**42.2 ppm**
Format	**20 Test Kit**
Analysis Time	**30 minutes per sample**
Sample Throughput	**6 samples per hour**
Operational Temperature Range	**40°F to 100°F**
Storage Temperature	**Room temperature**
Shelf Life*	**12 months at 80°F**
Confirmatory Laboratory Method	**EPA Method 8330**

*Guaranteed 2 months upon delivery. Call the Order Department for current kit shelf life.

APPLICATIONS

Industries:

- Army Ammunition Manufacturing Facilities
- Depots and Explosives Ordinances
- Disposal Sites

- Delineation of soil contamination
- Monitoring remediation and treatment

FINAL

HEALTH AND SAFETY PLAN ADDENDUM PILOT SCALE TREATABILITY STUDY FOR EXPLOSIVES-CONTAMINATED SOIL

NAVAL WEAPONS STATION YORKTOWN
YORKTOWN, VIRGINIA

CONTRACT TASK ORDER 0365

JULY 31, 1996

Prepared for:

DEPARTMENT OF THE NAVY
ATLANTIC DIVISION
NAVAL FACILITIES
ENGINEERING COMMAND
Norfolk, Virginia

Under:

LANTDIV CLEAN Program
Contract N62470-89-D-4814

Prepared by:
BAKER ENVIRONMENTAL, INC.
Coraopolis, Pennsylvania

ADDENDUM

PREFACE

The purpose of this Health and Safety Plan (HASP) Addendum is to provide specific health and safety information for a pilot test study to be conducted at Site 22 on soil collected from Site 7 at the Naval Weapons Station Yorktown, Yorktown, Virginia (WPNSTA Yorktown). Explosive contaminated soil identified at previously studies areas of Site 7 will be bioremediated at a biocell constructed at Site 22 at WPNSTA Yorktown. Subcontractors will be responsible for excavation of the contaminated soil, installation of biocell, and operation and maintenance of the biocell. These subcontractors will develop operation-specific HASPs prior to field activities. It is acknowledged that this HASP is designed for the protection of Baker personnel who will be performing general oversight and sampling tasks during the Pilot Study.

General information that is required for this HASP Addendum is presented in the Master Site HASP and identified in the Table of Contents with italicized print; this information will not be repeated here. Specific information to the proposed field activities for the pilot study is presented in bold print according to the same section numbers as the Master Site HASP. Prior to the startup of the field activities, site personnel are to review the Master HASP, this Addendum, and the HASPs provided by the subcontractors specific to the operation of the biocell. Each individual must certify that they have received the briefing, and that they understand the health and safety precautions by signing a Baker Health and Safety Training Record.

TABLE OF CONTENTS*

**Italicized print* indicates that information in that section is presented in the Master Site HASP.

TABLE OF CONTENTS*
(Continued)

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TABLE OF CONTENTS*
(Continued)

*Italicized print indicates that information in that section is presented in the Master Site HASP.

LIST OF TABLES

LIST OF FIGURES

*Italicized print indicates that information in that section is presented in the Master Site HASP.

LIST OF ACRONYMS AND ABBREVIATIONS

Baker	Baker Environmental, Inc.
CPR	Cardiopulmonary Resuscitation
HASP	Health and Safety Plan
LANTDIV	Atlantic Division, Naval Facilities Engineering Command
PHSO	Project Health and Safety Officer
PPE	Personal Protective Equipment
ppm	part per million
RI	Remedial Investigation
SHSO	Site Health and Safety Officer
USEPA	United States Environmental Protection Agency
WPNSTA Yorktown	Naval Weapons Station Yorktown, Yorktown, Virginia

2.2 Site-Specific Personnel

The following personnel will be responsible for the activities to be performed at Sites 7 and 22 (the responsibilities for these personnel are described in Section 2.2 of the Master Site HASP):

Baker Site Personnel/ Site Manager/ Site Health and Safety Officer (SHSO)	-	To be named
Project Health and Safety Officer (PHSO):	-	Ronald Krivan
Subcontractor Companies:		
Pilot Study Subcontractor	-	J.R. Simplot Company
Laboratory Subcontractor	-	Weston Environmental Metric, Inc.
Environment Sampling Subcontractor	-	Engineering and Environment, Inc.

3.2 Description of the Biocell Area

Due to the large area of flat land available at Site 22, the biocell will be constructed at this site; however, no investigative activities specific to Site 22 will occur. All sampling efforts and general maintenance of the biocell will be performed by Baker personnel at Site 22. EnSys kit testing of the soil samples collected from Site 7 and the biocell will be conducted at the Baker field trailer at WPNSTA Yorktown. Specific descriptions of the biocell will be provided in the workplans developed by the appropriate subcontractors.

3.3 Hazard Evaluation

The pre-entry briefing will serve to address the hazards particular to the pilot study. If additional hazards are identified by site personnel, they will be added to this HASP Addendum, and the Project Health and Safety Officer (PHSO) and Project Manager will be informed.

3.3.1 Chemical Hazards

Round Two Remedial Investigations (RIs) have been conducted at Site 7, from which the soil will be removed and remediated. Based on the results of the RI, this pilot study was designed to bioremediate explosive contaminated soil. Table 3-1 identifies the chemical/physical properties of the explosive constituents detected in the soil at Site 7, the highest concentration detected at the site, and routes of entry for the explosives. This information provides the basis for the chemical hazard determination by the PHSO. It contains a summary of the most current analytical data which will be used by the SHSO, field team members, subcontractors, visitors, and regulatory agencies as one means by which they can ascertain their potential risk to chemical hazards.

Chemical/Material Safety Data Sheets for explosive constituents that were previously identified at WPNSTA Yorktown have been compiled, and are included as Appendix B to the Master Project Plans. The data presented herein reflects the chemical/toxicological properties of the specific compound in a pure, non-diluted state. As such, when these compounds are detected in environmental media, the hazards are anticipated to be substantially less than those associated with exposure to "pure" compound. The data presented in the Chemical/Material Safety Data Sheets will,

therefore, be utilized as reference information when questions arise as to a constituent's chemical/toxicological properties, or measures for emergency response.

The potential for exposure, via inhalation, ingestion, dermal and/or eye contact absorption, to the chemicals detected during previous sampling investigations is feasible; however, given these routes of exposure, personnel can be adequately protected and exposure reduced or eliminated by engineering controls such as safe procedural sampling techniques conducted in upwind locations, administrative controls such as effective training programs, and personal protective equipment (PPE) such as chemical protective clothing.

3.3.3 Radiation Hazards

Given the history of these sites, a radiation survey meter will not be assigned.

3.3.5 Task-Specific Hazards

Baker personnel at the site, in conjunction with subcontractor personnel, will be responsible for confirmatory soil sampling during the excavation activities at Site 7; periodic collection of slurry samples from the biocell; and general maintenance of the mixer used in the biocell. A summary of potential hazards associated with the field activities is presented below.

The biocell located at Site 22 will be a 86 feet by 150 feet in ground structure, approximately 7 feet deep. An OSHA-approved gantry system and ladder will be constructed over the biocell. Baker personnel collecting samples from the biocell will climb the ladder to the top of the gantry and use a safety belt and lanyard mounted to the gantry for fall protection. The buddy-system will be used at all times during the sampling and maintenance activities at the biocell.

Aside from potential hazards associated with the biocell, the environment at Sites 7 and 22 may also pose other types of hazards. The presence of feral and poisonous animal life, uneven terrain, and possibly spiders, ticks, and chiggers are to be expected.

4.2 Site Conditions

Field activities are planned for the summer/fall of 1996, the weather conditions are anticipated to be warm and humid with occasional showers and afternoon thunderstorms. Winds generally will be from the southwest. Site 7 is a small drainage way on a hilllside leading to a marshy area. The biocell will be located in a level area of Site 22.

5.0 ENVIRONMENTAL MONITORING

Environmental monitoring is not required for the field activities proposed for the pilot study. The primary chemical hazards of concern are explosives. Since explosives are not volatile compounds; air monitoring will not be required.

6.0 PERSONAL PROTECTIVE EQUIPMENT

The assigned levels of protection for the Baker field activities are presented below. The item number corresponds to the table found in the Master Site HASP. Protection upgrades or downgrades will be based on working conditions and the discretion of the SHSO.

Item Number	Personal Protective Equipment
4	Normal Work Clothes or Coveralls
12	Chemical-Resistant Gloves (nitrile-inner-double layer)
13	Chemical-Resistant Gloves (nitrile-inner-single layer)
15	Chemical-Resistant Gloves (nitrile-outer)
16	Work Gloves (as necessary)
18	Chemical-Resistant Over boots (w/o steel toe)
19	Steel-Toe Boots
20	Safety Glasses
23	Hard Hat

8.0 EMERGENCY PROCEDURES

Much of the information regarding emergency procedures is presented in the Master Site HASP; however, this information is of such importance that some sections are repeated here with some additional information.

8.5 Emergency Medical Treatment and Telephone Numbers

The emergency medical treatment facility information and emergency telephone numbers, as identified below, will be posted in the Baker field trailer and maintained in each Baker field vehicle. A permanent telephone will be in place in the Baker field trailer. Mobile telephones will be available for health and safety emergencies. Operating instructions will be reviewed during site mobilization. Two-way radios will be utilized for internal communications between the field personnel when WPNSTA Yorktown provides the proper clearance and authorization for use.

Emergency Medical Services

For non-chemical exposure incidents (i.e., cuts, bruises, sprains, heat stress), the nearest public hospital is (refer to Figure 8-1):

Mary Immaculate Hospital
800 Denbigh Boulevard
Newport News, VA 23602
(804) 886-6000 (General Information)
(804) 886-6437 (Emergency Room)

Note: In emergency situations, personnel may be transported to Building 1806, which is the WPNSTA Yorktown Branch Medical Clinic, for initial treatment.

For chemical exposure incidents (i.e., skin rash due to contact with contaminated media, inhalation of organic vapors), the nearest public hospital is (refer to Figure 8-2):

Riverside Regional Medical Center
500 J. Clyde Morris Boulevard
Newport News, Virginia 23601
(804) 594-2000 (General Information)
(804) 594-2050 (Emergency Room)

Local ambulance service is available from:

Name	Branch Medical Clinic
On-Station Emergency Telephone No.	x 4911
On-Station Non-Emergency Telephone No.	x 7404
Off-Station Emergency Telephone No.	(804) 887-4911
Off-Station Non-Emergency Telephone No.	(804) 887-7404

Contact will be made with emergency personnel at the pre-construction meeting.

Emergency Telephone Numbers

Table 8-1 presents the necessary emergency telephone numbers for both on-Station and off-Station telephones.

8.6 Emergency Hospital Route

An emergency hospital route for off-site public hospitals and a building identification map for the Branch Medical Clinic (Building 1806), will be posted in the Baker field trailer and maintained in each Baker field vehicle. Personnel will be informed of the location of each of the maps and the directions to the hospital at the pre-entry briefing. The directions to each of the public hospitals are presented in Figure 8-3.

8.7 Injuries

If injuries are not serious or life threatening, affected personnel may be transported by other site personnel to the local medical facility, if necessary. Emergency medical response personnel also will be contacted in the event of serious or multiple injuries. Medical personnel will be provided with all available information regarding the nature of the incident, chemicals involved, etc. Instances requiring treatment beyond "First Aid" will be handled at appropriate facilities and reported to the Project Manager and PHSO within 24 hours.

There will be a minimum of two persons during each phase of field activities that will be trained in standard first aid and adult cardiopulmonary resuscitation (CPR). These personnel also will be familiar with Baker's program for potential exposure to blood borne pathogens. Subcontractors will be responsible for securing proper medical attention for their employees. Baker may assist the subcontractors as necessary.

8.7.1 Physical Injury

If an employee working in a contaminated area is physically injured, first aid procedures will be followed. If the employee falls off of the gantry system into the biocell and is unable to remove himself from the cell, the individual will be pulled from the biocell with the safety belt and lanyard system. If the employee can be moved, the individual will be taken to the edge of the work area and decontaminated, if necessary (refer to Section 8.8 of the Master Site HASP). Depending on the severity of the injury, emergency medical response from WPNSTA Yorktown Branch Medical Clinic personnel may be sought to stabilize the victim for transport to a public hospital. Emergency first aid may be administered by Baker personnel prior to transporting to an awaiting ambulance or to a local emergency medical facility, as necessary.

8.7.2 Chemical Injury

If the injury to a worker is chemical in nature (e.g., direct contact or exposure), the following first aid procedures will be instituted immediately:

- Eye Exposure - If contaminated solid or liquid gets into the eyes, wash the eyes immediately at the 15-minute emergency eyewash station or with the personal eye wash bottle when an eye wash station is not immediately available. Obtain medical attention immediately.

  NOTE: Contact lenses will not be worn while working at any site.

- Skin Exposure - If contaminated solid or liquid gets on the skin, promptly wash the contaminated skin using soap or mild detergent and water. If solids or liquids

penetrate through the clothing, remove the clothing immediately and wash the skin using soap or mild detergent and water. Obtain medical attention immediately.

- Swallowing - If contaminated solid or liquid has been swallowed immediately contact the Central Virginia Poison Information Services at (804) 786-9123. Do not induce vomiting in an unconscious person. Obtain medical attention as directed by the Poison Control Center.

- Breathing - If a person has difficulty breathing, move the exposed person to fresh air at once. If breathing is not evident, check for pulse and perform appropriate first aid, either rescue breathing or CPR, depending on the condition. Obtain medical attention immediately.

Procedures to follow in the event of an exposure to hazardous chemicals/wastes are located in Attachment A of this HASP Addendum.

8.7.3 Snakebite Injury

In the event of a snakebite injury, the following procedures will be followed.

Look for signs and symptoms such as the characteristic appearance of two small holes, usually about a half inch apart, with surrounding discoloration, swelling, and pain. Systemic signs, which may or may not occur, include weakness, sweating, faintness, and signs of shock.

Provide treatment as follows:

1. Calm the victim and keep affected area still.
2. Contact ambulance if you cannot provide victim with transportation to the nearest medical facility.
3. Wash the wound.
4. Keep the affected area below the level of the heart if bite is on the arm or leg.
5. Treat for shock.

6. Monitor airway, breathing, and circulation.

7. Obtain physical description of snake, if possible.

8. Provide the emergency medical responder, either the ambulance attendant or the emergency room at the hospital, with all pertinent information such as: how long ago the bite occurred, the type of snake (if known), any known allergic conditions (if known), etc.

9. Inform the SHSO as soon as possible.

8.7.4 Spiderbite Injury

There are two spiders commonly found in the United States whose bite can be serious: the black widow spider and the brown recluse spider. These bites may be serious, even life-threatening. Many other spiders will bite, but they do not produce serious complications. The black widow spider measures approximately 1 inch long with its legs extended. It is glossy black in color and has a distinctive yellow-orange marking in the shape of an hourglass on its belly. On its back, however, there is no marking, and unless you happen to turn the spider over, you cannot see this mark. The danger of the black widow spider bite lies in its systemic manifestations. The venom from this spider attacks the nervous system, resulting in severe muscle cramps with boardlike rigidity of the abdominal muscles, tightness in the chest, and difficulty in breathing. Sweating, nausea, and vomiting also will occur.

The emergency treatment for the black widow spider bite is basic life support. Sometimes the individual is not even aware of having been bitten, or where. Apply cold to the site of the bite if it can be identified. There is a specific antivenom for this spider bite that must be administered by a physician. It is particularly important to identify the spider, and bring it in, if you can.

The brown recluse spider is a little bit smaller than the black widow spider and is dull brown in color. It has a violin-shaped mark on its back, which can be seen when you are looking at the spider from above. The spider gets its name because it tends to live in dark areas, corners, and old unused buildings. The bite from this animal produces local rather than systemic manifestations. The venom of the brown recluse spider causes severe local tissue damage and can lead to an ulcer and gangrene. The bitten area becomes red, swollen, and tender within a few hours after the bite. A small blister forms, and several days later, this may form a large scab, covering a deep ulcer. Death is rarely

reported, but these bites need surgical treatment, and these patients should be brought to the hospital. Again, if possible, identification of the spider should be carried out.

9.2 Site-Specific Training

Training requirements are specified in Section 9.0 of the Master Site HASP.

11.0 HEALTH AND SAFETY PLAN APPROVAL

This HASP Addendum for the Pilot Study to be conducted at Site 22 has been reviewed by the following personnel prior to submission to Atlantic Division, Naval Facilities Engineering Command (LANTDIV).

To be named	Site Manager	_____
(Name)	(Role)	(Signature)
Ronald Krivan	Project Health and Safety Officer	_____
(Name)	(Role)	(Signature)
Tammi Halapin	Project Manager	_____
(Name)	(Role)	(Signature)

12.0 DECLARATION OF HASP REVIEW*

All site personnel indicated below have reviewed and are familiar with the Master Site HASP and this HASP Addendum for the pilot study to be conducted at WPNSTA Yorktown.

(Name-Print)	(Company)
(Name-Sign)	(Date/Time)
(Name-Print)	(Company)
(Name-Sign)	(Date/Time)
(Name-Print)	(Company)
(Name-Sign)	(Date/Time)
(Name-Print)	(Company)
(Name-Sign)	(Date/Time)
(Name-Print)	(Company)
(Name-Sign)	(Date/Time)

* This page is to be reproduced to accommodate the members of personnel who receive training prior to performing activities or visiting a site, and is to remain in the Baker field trailer until demobilization.

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TABLES

TABLE 3-1

CHEMICAL/PHYSICAL PROPERTIES OF THE EXPLOSIVE CONSTITUENTS DETECTED IN THE SOIL COLLECTED FOR PILOT SCALE TREATABILITY STUDY NAVAL WEAPONS STATION YORKTOWN YORKTOWN, VIRGINIA

Chemical	Highest Concentration Detected (ppb)	Exposure Limit (EL)[1]	Vapor Pressure[2]	Ionization Potential	Routes of Entry
Explosives: HMX	3,200,000	NA	NA	NA	Inhalation, Absorption, Ingestion, Skin/Eye Contact
RDX	14,000,000	1.5 mg/m^3 (skin)	NA	NA	Inhalation, Absorption, Ingestion, Skin/Eye Contact
2,4,6-TNT	40,000,000	1.5 mg/m^3 (skin)	0.05 (at 180°F)	10.59 eV	Inhalation, Absorption, Ingestion, Skin/Eye Contact

Notes:

(1)

EL - Exposure Limit = A time-weighted average concentration for a normal eight-hour work day and 40-hour work week, to which nearly all workers may be repeatedly exposed, day after day, without expected adverse effect. The EL represents published Exposure Limits according to the following hierarchical order: (1) OSHA PELs; (2) NIOSH RELs; (3) ACGIH TLVs; and, (4) Other recognized sources.

(2)

Vapor Pressure = Expressed as mm/Hg at 68°F (unless otherwise mentioned).

ppb = parts per billion
NA = Not Available
mg/m^3 = milligrams per cubic meter (in air)
Skin = Potential for dermal absorption

TABLE 8-1

EMERGENCY TELEPHONE NUMBERS
PILOT SCALE TREATABILITY STUDY
NAVAL WEAPONS STATION YORKTOWN
YORKTOWN, VIRGINIA

Facility	Phone Number On-Station Phone [1]	Phone Number Off-Station Phone [2]	Contact [3]
Emergency (One Call)	ext. 4911	(804) 887-4911	Dispatch
Spill Response	ext. 4676	(804 887-4676	Dispatch
Hot Work Permits	ext. 4950	(804) 887-4950	Asst. Fire Chief Dinkins
Fire	ext. 4911	(804) 887-4911	Dispatch
Security	ext. 4676	(804) 887-4676	Response Operator
Ambulance (Branch Medical Clinic)	ext. 4911	(804) 887-4911	Dispatch
Ambulance (Public)	(9) 911	911	Response Operator
Branch Medical Clinic (Non-Emergency)	ext. 7404	(804) 887-7404	Tommy Stainback, RN
Branch Medical Clinic (Emergency)	ext. 4911	(804) 887-4911	Tommy Stainback, RN
Public Hospital (Chemical Exposure)	(9) 594-2050	(804) 594-2050	Emergency Room Attendant
Public Hospital (Non-Chemical Exposure)	(9) 886-6437	(804) 886-6437	Response Operator
On-Scene Coordinator	ext. 4911	(804) 887-4911	Dispatch
Central Virginia Poison Information Services	(9) 786-9123	(804) 786-9123	Response Operator
National Response Center	1-800-424-8802	1-800-424-8802	Response Operator
CHEMTREC (Chemical Transport Emergency Center)	1-800-424-9300	1-800-424-9300	Response Operator

Notes:

[1] When using the trailer phone, use the "887" prefix when calling on-station.

[2] When using a mobile phone at WPNSTA Yorktown, dial the complete number, including area code.

[3] Points of contact will be reconfirmed during site mobilization.

FIGURES

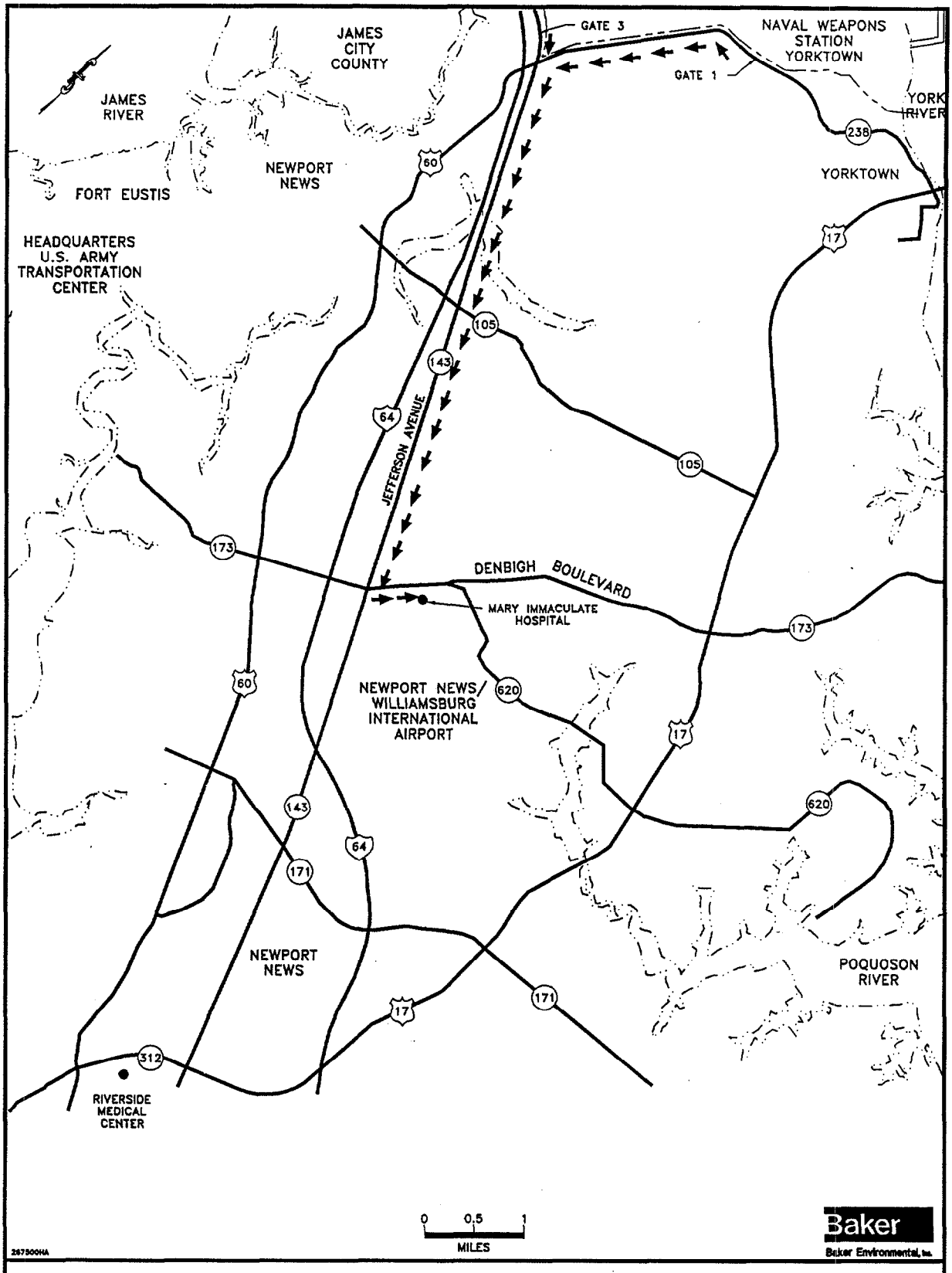

FIGURE 8-1
EMERGENCY HOSPITAL ROUTE
NON-CHEMICAL EXPOSURE INCIDENTS
MARY IMMACULATE HOSPITAL

NAVAL WEAPONS STATION YORKTOWN
YORKTOWN, VIRGINIA

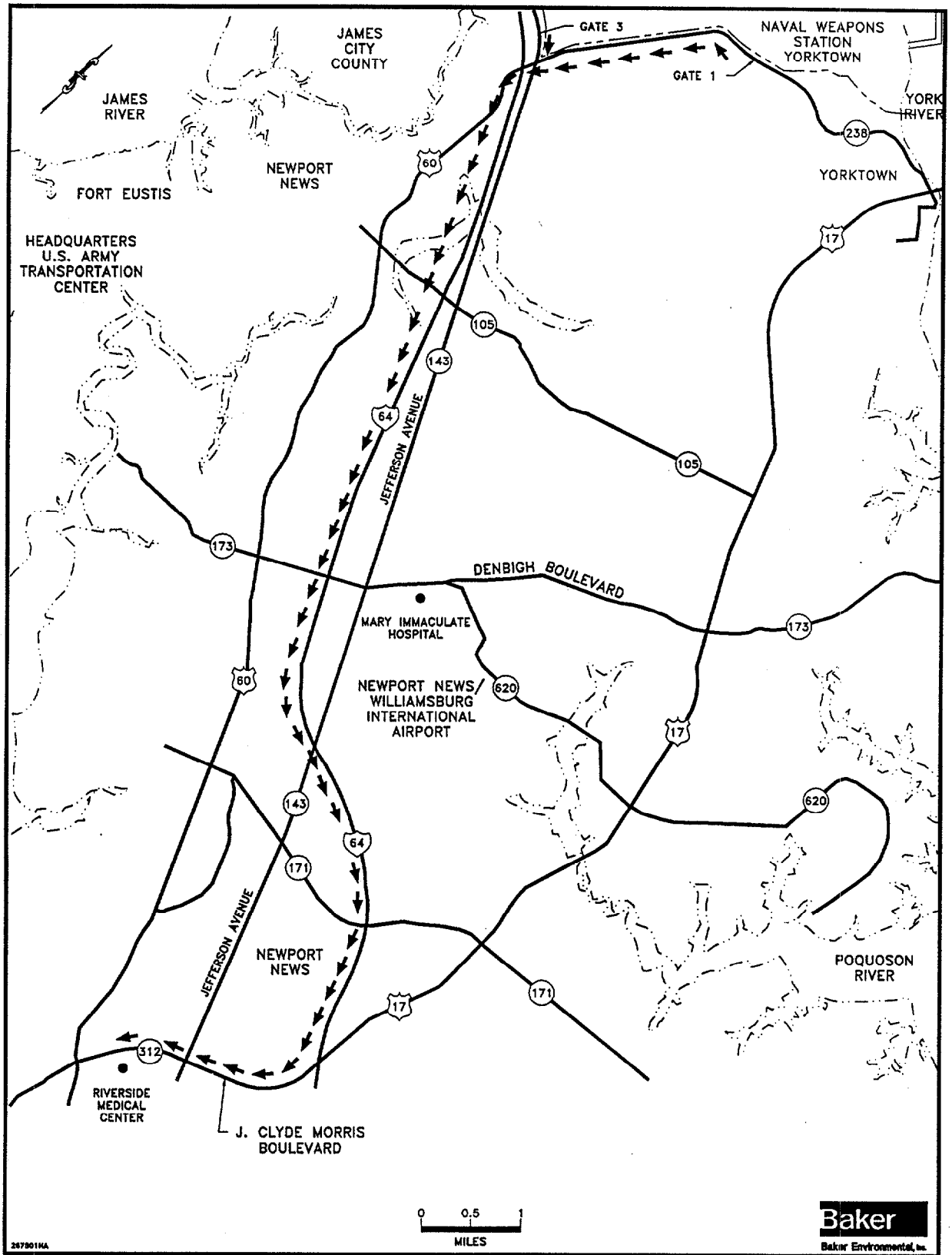

FIGURE 8-2
EMERGENCY HOSPITAL ROUTE
CHEMICAL EXPOSURE INCIDENTS
RIVERSIDE MEDICAL CENTER

NAVAL WEAPONS STATION YORKTOWN
YORKTOWN, VIRGINIA

FIGURE 8-3

WRITTEN DIRECTIONS TO PUBLIC HOSPITALS

Non-chemical Exposure Incidents - Mary Immaculate Hospital (refer to Figure 8-1):

Gate 1

1 From Gate 1 proceed south (turn right) on State Route 238 until intersecting with State Route 143 (approximately 2.4 miles).
2 Turn left, following State Route 143 south for approximately 5.3 miles until intersecting with Denbigh Boulevard.
3 Turn left onto Denbigh Boulevard and proceed east until intersecting with McManis Boulevard, following signs for emergency room entrance.

Gate 3

1 From Gate 3 turn left and proceed south on Route 143 for approximately 5.5 miles until intersecting with Denbigh Boulevard.
2 Turn left onto Denbigh Boulevard and proceed east until intersecting with McManis Boulevard, following signs for the Emergency Room Entrance.

Chemical Exposure Incidents - Riverside Medical Center (refer to Figure 8-2):

Gate 1

1 From Gate 1 proceed south (turn right) on State Route 238 until intersecting with Interstate 64 (approximately 2.5 miles).
2 Follow Interstate 64 east (southeast) for approximately 11.0 miles until intersecting with J. Clyde Morris Boulevard (State Route 312) at Exit 258A.
3 Proceed west-southwest for approximately 2.3 miles, Riverside Medical Center will be on the left-hand side.
4 Follow signs for Emergency Room Entrance.

Gate 3

1 From Gate 3 proceed south (turn left) onto State Route 143 until intersecting with Route 238 (approximately 0.2 miles).
2 Turn right then move into left lane to access Interstate 64 south.
3 Follow Interstate 64 east (southeast) for approximately 11.0 miles until intersecting with J. Clyde Morris Boulevard (State Route 312) at Exit 258A.
4 Proceed west-southwest for approximately 2.3 miles, Riverside Medical Center will be on the left-hand side.
5 Follow signs for Emergency Room Entrance.

UPON ARRIVING AT RIVERSIDE MEDICAL CENTER, FOLLOW THE PROCEDURES OUTLINED IN ATTACHMENT A ENTITLED "EMERGENCY PROCEDURES FOR EXPOSURE TO HAZARDOUS CHEMICALS/WASTE".

ATTACHMENT A
EMERGENCY PROCEDURES FOR EXPOSURE TO HAZARDOUS MATERIALS/WASTE

ATTACHMENT C

EMERGENCY PROCEDURES FOR EXPOSURE TO HAZARDOUS MATERIALS/WASTE

1. Call ambulance or transport individual to hospital/clinic immediately. Monitor airway, breathing and circulation during trip to hospital or while waiting for the ambulance. Administer first aid or CPR, as necessary. Don't forget to take the HASP Addendum with you; it contains information on the contaminants expected to be found on site and will assist the physician in his/her assessment of the exposure.

2. Fill in Potential Exposure Report, answering each of the questions to the best of your ability.

3. Contact our physician(s) at EMR as soon as possible. The procedure is as follows:

    a. **Call EMR at 1-800-229-3674!**

    b. Ask to speak with:

    Dr. David L. Barnes;
    Dr. Elaine Theriault; or
    Ms. T.J. Wolff, R.N.

Note: During nonbusiness hours (after 6 p.m.) call 1-800-229-3674 and follow directions for paging the aforementioned individuals.

4. Once in contact with any of these individuals, explain what has happened (they will review the information on the form with you and may ask you to fax the form to them, if possible), and allow either of them to speak with the attending physician.

5. When asked about payment (and they will ask), inform the Hospital/Clinic/Physician that this is a "work related injury" and have them contact Teresa Nelson at (412) 269-4655. Have invoices sent to:

    Michael Baker Jr. Inc.
    Attn: Benefits Coordinator
    Airport Office Park, Bldg. 3
    Coraopolis, PA 15108

6. Contact the Project Manager and the Project Health and Safety Officer as soon as it is feasible, but wait no longer than 24 hours.

ATTACHMENT B
BAKER ENVIRONMENTAL, INC.
SAFETY STANDARD OPERATING PROCEDURES

(Refer to Master Site Health and Safety Plan)